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Carbon Fibres/Carbon Cloths/Metal Impregnants Historical Perspective/Surface Properties, Activation and Adsorbent Uses

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Historical Perspective/Surface Properties, Activation and Adsorbent Use

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Carbon Fibres

1. Introduction

Carbon fibres can be produced from a variety of precursor materials including rayon, polyacrylonitrile (PAN) and pitch materials [1]. When these carbon fibres are activated, it is possible to produce a material with low hydrodynamic resistence which may be used as an adsorbent for treatment of high gas flows. Elimination of the channelling and settling which often occurs with powdered or granular carbons can be achieved with the selection of textile form (woven, nonwoven etc.). The raw material dictates the price of the final product. Fibres produced from the cheaper cellulosic raw materials were often the fibre of choice for many of the initial research investigations and applications. Later pitch-based fibres became the focus of many studies.

1.1 In the Beginning

Some preliminary work on carbon fibres was carried out in the early 1960s. The investigations studied the bulk properties of fibres created from the pyrolysis of polyvinyl alcohol [2], PAN [3] and cellulose [4 5] but these fibres were rarely activated. Later the surface properties of carbonised rayon fibres were studied [6] and fibres were made from a Saran precursor material [7 8] with reported surface areas in excess of 1000 $m^2.g^{-1}$. Economy et al. produced carbon fibres from novolac, a phenolic resin [9]. Work on mesophase pitch-based fibres had increased tremendously by the mid 1970s [10]. A process for producing fibres from mesophase pitch was patented by Union Carbide Corporation [11] which later was referenced by 37 other patents. Numerous patents on

carbonised PAN fibres were issued [12] [13] [14], for example.

Alternative methods of holding a carbon-based material in a fabric type of formation were also investigated which did not always include a carbon fibre per se but a carbon impregnated cloth. Early work at Porton Down [15] looked at the changes in the adsorption properties of latex coated carbon. The difficulty with these materials not only included pore blocking but also in maintaining a homogeneous distribution of carbon particles within the latex mixture. Quilted [16] and laminated [17] materials with high adsorption capacities were starting to be developed. These both contained carbon fibres trapped between other materials. Giglia patented at flocked laminate fabric which layer materials with both activated carbon fibres and an activated carbon powder [18]. Carbon yarns were also knit into fabrics [19] and Jonas et al. retained finely divided ASC carbon with fibres [20]. Skala et al. reported benzene breakthrough curves on activated carbon-impregnated polyurethane foam in 1988 [21].

2. Viscose Rayon Cloth

A carbonised viscose rayon cloth had already been touted as a "*new activated carbon adsorbent*" [22] and was used in adsorption from solution studies. The cloth in question had been manufactured by the Chemical Defence Establishment (CDE), Porton Down [23] and much of the ground-breaking work had been done by Maggs and coworkers [24] to establish that the efficiency of adsorption from the gas phase under dynamic conditions on ACC (activated carbon cloth) was better than with granular activated carbon. One adsorptive device actually attempted to exploit the positive aspects of both carbon fibres and granules by combining them in one filter [25].

In 1981 the adsorption and enthalpy of immersion properties of a cloth sample were compared to the highly-activated Amoco PX-21 powdered carbon [26]. This viscose rayon carbon cloth was treated with chemical impregnants and tested for the adsorption of low boiling gases [27] and for the agglomeration of the metal impregnants [28]. Maggs and Capon also studied the kinetics of activation of the cloth when doped with different metal ions [29] and Smith and Davies compared the adsorptive performance under humid conditions of CDE cloth with granular carbon [30]. A patent was issued claiming a waterproof carbon cloth could be created by depositing a thin layer of hydrophobic material such as polytetrafluoroethylene on the surface [31].

3. Impregnation /Metals on the Surface

American patents reported the use of carbon cloths or felts with metal dispersions as surgical dressings [32 33]. The antibacterial actions of silver impregnated, phenolic resin-based fibre was later studied by other groups. These investigations concluded that the activated fibres work against common bacteria but the impregnant (Ag) would leak out in aqueous solution [34] and high surface areas were hard to achieve [35]. Later the group attempted to hold silver on a carbonised methacrylate-grafted phenol resin fibre showing that the antibacterial action depended on a combination of surface area and silver content [36]. Silver was then combined with cobalt in a phenolic resin to increase the mesopore volume of the fibre [37]. Others observed an increase in concentration of oxygen containing functional groups and a decrease in BET surface area when silver was deposited on the surface from aqueous solution [38]. (This work is continuing.)

A very detailed paper appeared in 1985 on the adsorption of phosphine on the CDE carbon cloth with and without impregnants [39]. This paper, which included the detrimental effects of water vapour, concluded that copper nitrate was a more effective impregnant than silver nitrate for phosphine adsorption. Investigations of metals on carbon fibre surfaces continued and included catalyst support work [40] on PAN-based fibres which had been activated conventionally (air or steam) and by a novel microwave discharge technique.

4. Carbon-Lorraine: A Woven Carbon Cloth

Extensive studies on a commercially available carbon cloth (TCM 128) supplied by Carbon-Lorraine, France, were carried out by Koresh and coworkers. The first portion of these studies emphasized the molecular sieving aspects of these materials and how gradual pore opening could be exploited [41], how cross-sectional molecular dimensions could be estimated [42] and the kinetics of adsorption of various gases [43]. The molecular sequence of hydrogen and oxygen adsorption on carbon cloths with increasingly wider pores was also demonstrated [44]. Later the carbon fabrics were subjected to various forms of oxidation and studies on these oxidised samples included several aspects of the interaction of water vapour with the carbon, such as the role of surface oxide groups and pore constrictions [45], the enthalpy of immersion and thermal desorption studies [46] and adsorption-desorption hysteresis [47]. The development of pore structure with nitric acid oxidation of this material [48] and the use of electrical conductivity to study these surface oxides was also investigated [49]. A plasma activation of the same cloth was carried out [50], along with a further investigation of water adsorption on the

cloth treated with gaseous chlorine [51]. The cloths in these studies had very fine micropores and the selectivity for the adsorption of small molecules was demonstrated. However, the micropore volume accessible to nitrogen never attained a value greater than 0.24 $mL.g^{-1}$ making the material a poor substitute for a granular carbon adsorbent with a much higher total capacity for the bulk removal of organics.

5. Porosity and Adsorption

By 1984 higher surface area activated carbon cloths with predominately slit-shaped pores were being mentioned in the literature [52]. Extended studies of carbon-fibre microporosity included carbonised rayon-yarn [53], activated rayon-based carbon fibres [54] and impregnated cellulose based-carbon fibres [55]. Suzuki and coworkers investigated adsorption of organics from both the gas and liquid phase on a variety of carbon fibres from different sources [56]. Ismail looked at the microporosity of an assortment of fabrics and fibres [57], concluding that the pitch-based fibres had a narrower pore size and distribution than the rayon-based fabric [58]. A phosphoric acid pretreatment of the viscose rayon cloth was later investigated which was suspected of inhibiting pore narrowing in carbon fibre with heat treatment [59] and correlations between adsorption and x-ray diffraction studies were carried out [60]. Similar correlations between adsorption and small angle x-ray scattering of isotropic pitch-based fibres were demonstrated by others [61]. Ryu et al. looked at steam activated isotropic pitch-based fibres concluding the micropore size distribution broadens with increased weight loss [62, 63]. The results were similar to those of Li et al. [64]. Liu and coworkers studied the effect of carbon dioxide and steam activation of pitch-based fibres [65] and the uptake of organics

on these fibres [66]. Previously, the adsorption of noble metals on high surface area fibres was studied [67].

Zeng and coworkers have prepared many activated carbon fibres from a number of sources, including jute-based ACF and PEEK (polyetheretherketone) composites [68]. They studied not only vapour adsorption but also the removal of dyes, metals and organics from aqueous solution [69]. This group also studied redox reactions on the surface of the fibres [70 71 72] including the reduction of various metals [73] and the relationship between redox and adsorption properties [74]. Other Chinese groups have also looked at activated carbon fibres for removal of dyes from wastewater [75 76].

6. Surface Studies

Sherwood and coworkers investigated the surface properties of carbon fibres. The fibres were PAN based and the treatments were electrochemical in nature. Upon treating the fibres with ammonium bicarbonate, C-N groups were observed on the surface [77] while nitric acid treatment produced no such groups [78]. The C-N groups were found to be greatly enhanced by saturating the electrolyte solution with ammonia gas [79]. These nitrogen groups on the carbon surface may be a method of replacing the amine-based additives used in the present state of the art [80 81 82 83 84 85], for impregnated military carbons.

The acidity of PAN-based carbon fibres (Courtaulds XA), both untreated and electrolytically oxidised, was studied by Watts et al.[86]. Much of this work on fibres was for the carbon fibre-composite field where knowledge of the surface properties dictated the bonding potential of the fibre. This was addressed in an early review [87]. This field

also was concerned about the oxidation of the composites [88] at high temperatures which lead to studies on borate treatment of the fibres [89]. Boron containing impregnants were also added to viscose rayon cloths in a study of the rate of activation of the carbon cloth in carbon dioxide [90]. The same group continued the study with phosphate impregnants [91] and looked at the resulting mesopore development [92 93 94 95]. It was determined that controlling the pore structure, with changing impregnants, could tailor-make fibres for specific applications [96]. The study was later expanded to include transition metal compounds [97 98].

7. Impregnation before Pyrolysis

Polovina et al. studied the uptake of copper salts on viscose rayon cloth and the changes in the porosity of the pyrolyzed material as a result [99]. The pre-pyrolysis impregnants on the cloth were then expanded to include combinations of zinc, aluminium as well as ammonia , borate and phosphate salts [100]. An alternative method deserves mention and was developed by Morawski et al. who prepared pre-treated PAN carbons by dissolving polyacrylonitrile with metal salts but this was not spun into a fibre form before carbonising [101]. Kryazhev et al. also pre-impregnated cellulose fibres with various transition metals, which were said to catalysed the dehydration and suppress carbon-containing product formation resulting in higher yields [102].

8. Hydrogen Cyanide Uptake

Extended studies on CDE viscose rayon cloth continued and included developing novel impregnation techniques for metal loadings of copper and chromium compounds [103 104 105], cobalt and nickel compounds [106] and metal carboxylates [107], for the removal of

hydrogen cyanide from gas streams [108]. Later the copper impregnated cloths were investigated for the decomposition of formic acid [109] and chromium adsorption from aqueous solution [110].

A different cloth (Toyobo-Osaka), also rayon-based, was impregnated with various combinations of metal cation/organic salt mixtures in the study of HCN uptake [111]. Copper (II) tartrate was found to be the best impregnant while salts of magnesium and aluminium showed no affinity for HCN.

9. Amine and the Surface Groups

Sandle and Varghese investigated amine adsorption on carbon cloth with and without oxygen groups [112], concluding that the uptake of n-butylamine does not correlate directly with the carboxylic groups on the surface. Amine adsorption was determined to be the result of the cumulative effects of physical adsorption, weak chemical interaction and ammonium salt formation.

10. Increasing the Adsorption Capacity

A KOH-activation of both viscose rayon cloth and a petroleum pitch-based fibre mat was successfully carried out by Audley et al., who managed to keep the fibre intact and create a high surface area [113 114]. Lewis et al. also used this type of harsh activating conditions on various fibres (isotropic pitch fibres from Ashland, and mesophase pitch and rayon fibres from Amoco) with resulting high surface areas [115]. Both Kim et al.[116] and Jagtoyen et al. [117] compared steam activation to KOH activation of a PAN -based fibre. The chemically activated fibres had a higher N/C ratio than the steam treated samples. In a pre-impregnation of isotropic pitch with KOH, Przepiorski et al. prepared

an activated carbon fibre with a potassium carbonate dispersion for use as an alkali catalyst [118]. The relationship between the preparation technique of these potassium treated fibres and the uptake of hydrogen sulfide was presented in a subsequent study[119].

11. Protective Layers

Work continued on layered materials containing carbon in various forms and patents were issued on a ribbed carbon containing layer material said to be suitable for protective garments [120], a laminated fabric [121] and composite fabrics [122 123 124 125]. Much of these work was done for chemical protective garment usage and included patents on reduced stress vapour-sorptive garments [126] and waterproof fabrics [127 128]. Adsorption sheets were developed which consisted of carbon fibre and powder mixed with polytetrafluoroethylene[129]. Various packing densities of the material could be achieved by varying the concentrations of the mix or by changing the length and diameter of the fibre. Sheets could be processed which were bendable and handled easily. An early Canadian-based invention [130], for an open-celled carbon loaded foam structure, suffered disadvantages for respirator use due to its low density but the impregnation of polyurethane with carbon process was exploited twenty years later for protective fabric when superactivated carbons became available [131].

A very interesting study on the breakthrough of organics on layers of carbon cloth was presented in 1993 [132]. It was suggested that exhaled breath could pass through the filter bed inducing desorption of a portion of the vapour thus increasing the lifetime of the filter.

12. Conductivity and Electrodes

The electrical conductivity of the viscose rayon carbon cloth materials has also been measured. The study included the effects of porosity, temperature and the adsorption of either water or hexane on the conductivity [133].

Other aspects of the carbon fibre field such as the effect of temperature and heat-treatment on PAN-based carbon fibre electrodes has been reported in the literature [134]. Some of these surfaces were also modified by a nitric acid oxidation procedure [135]. More recent studies on surface modification involve nitric acid treatment of the PAN carbon fibre followed by a reaction with amines to introduce a high surface amine concentration [136] [137] and treatment with diazonium salts [138]. Again much of this work relates to the carbon-composite field and interfacial adhesion but may be valuable for the C-N surface group reaction scheme.

The surface properties of high area phenolic resin-based fibres were also studied in an attempt to explain the observed electrical double-layer properties of the fibres [139]. The fibres were investigated for nitrogen and carbon dioxide adsorption [140] and were also formed into sheets using natural pulps as binding materials [141]. The reduction properties of various activated carbon fibres were also studied [142]. Isotropic pitch-based fibres have also been investigated in electrical double layer capacitors [143]. All of these surface studies aid in the understanding of other phenomena occurring with these cloths and the impregnants.

13. Micropores in Viscose Rayon Based Carbon Cloth and Water Adsorption

The evolution of the micropore structure of a viscose rayon cloth (Moygashel Ltd.

Northern Ireland) was studied by Carrott and Freeman [144] which included water vapour isotherms. Surface excess isotherms of methanol and water were also reported [145]. This was followed by a study of water adsorption after the polymerization of isobutene in the micropores of the cloth [146]. In further attempts to make the carbon cloth more hydrophobic, ethylene oxide was deposited on the surface with some success [147].

14. The Work of Kaneko

Adsorption and Impregnation on Pitch and Cellulose-Based Carbon Fibres

Kaneko and coworkers studied the adsorption properties [148] of various microporous carbon fibres with and without metal loadings [149]. The loaded fibres were treated with iron dispersions for NO adsorption [150 151 152 153], NO_2 adsorption [154] and combined NO-H_2O adsorption [155]. Mixed gas adsorption with NO_x -SO_2 was also carried out [156]. These fibres were also compared to other adsorbents for the removal of nitrate ions from aqueous solution [157]. Later cellulose-based, iron-impregnated fibres were doped with copper with a resulting increase in the nitrogen micropore volume to above 0.7 $mL.g^{-1}$ [158]. Other mixed valence oxides were also investigated [159] including Ti(IV)-doped Fe oxides [160] and platinum electrodeposited on a cellulose-based activated carbon fibre [161]. In a study of pitched-based carbon fibres (Osaka Gas and Unichida), Kaneko et al. looked at the fine microporosity by comparing the adsorption of helium to nitrogen [162], by small angle x-ray scattering[163] and by the adsorption of NO, SO_2 and NH_3 [164 165 166]. The pitch-based fibres were also doped with copper and iron oxides [167] and cellulose-based fibres were doped with Ru [168] and other metals for NO adsorption [169]. The group investigated the origin of the large measured surface areas greater than

2000 $m^2.g^{-1}$ [170]. The swelling of the micropores due to the adsorption of water on both cellulose-based and PAN-based fibres was also studied [171] [172], along with the changes that occurred when these fibres were heat treated [173]. This group treated cellulose-based carbon fibres (Toyobo Co.) with fluorine and studied the water adsorption [174], which was greatly reduced throughout the entire relative pressure range (referred to as perfect hydrophobicity). The surface area of the fluorinated fibre also dropped to 532 $m^2.g^{-1}$ compared with 1147 $m^2.g^{-1}$ for the non-fluorinated fibre[175]. Continuing studies including pitch-based fibres confirmed the significant decrease by fluorination of the micropore volumes of the fibres [176], and while the structure of the micropore was preserved with fluorination, the micropore width decreased [177].

15. Novalak Resin Fibres

A method of producing a high surface area fibre using a novel impregnation technique was patented in 1991 by Arita et al. [178]. In this procedure novalak resin fibres were impregnated with a secondary monomer which was then polymerised before carbonisation in an oxidising atmosphere. A higher yield of a product was reported.

16. Gas-Phase Activation

The mechanical properties of carbon dioxide-activated PAN-based carbon fibres were investigated [179] and steam-activated and carbon dioxide viscose rayon chars with various impregnants were studied [180] [181] [182]. Ammonia was also investigated as an activating agent with the conclusion that two types of nitrogen containing groups could be formed in the char [183]. The activation of isotropic pitch-based carbon fibres (Kureka) with steam and carbon dioxide showed different results with the two activating agents

[184]. PAN-based carbon fibres also differed with activating agent [185]. This conclusion was reaffirmed by another group stating that the activated diffusion coefficient for carbon dioxide was larger than that of steam, hence steam activates carbon fibres via reaction with the external surface (reducing the diameter of the fibre) and CO_2 generates micropores [186] [187] . In a later study of the same fibres it was determined that the external gasification with steam occurs after 40% weight loss [188]. (Some of the reasoning behind the conclusions about the steam versus carbon dioxide activation has been disputed by Walker [189] and again re-explained with additional data [190].) The gasification of PAN-based fibres in steam and the inhibiting effect of both hydrogen and carbon monoxide has been studied. Hydrogen was a more effective inhibitor than CO [191].

Ehrburger et al. actually describe a swelling of isotropic pitch-based fibres on carbon dioxide activation [192]. This phenomenon was not observed with steam nor was it observed with phenolic resin-based fibres [193]. The active surface area of a phenolic resin-based fibre was found to remain almost constant with gasification [194]. Other papers on the modelling of the gasification of carbon fibres can be found in the literature [195] as well as the kinetics of the activation [196].

17. Impregnation Followed by Activation

Linares-Solano et al. dispersed platinum in phenolic resin-based activated carbon fibres by two methods, comparing a pre-pyrolysis treatment with an impregnation of the carbon fibre [197]. Both of the fibres were activated with carbon dioxide after metal impregnation. The resulting pre-treated carbon fibres contained more mesopores. This production of mesopore was attempted in similar phenolic resin-based fibres by doping

the precursor with cobalt before processing, carbonising and activating with steam [198]. Cobalt accelerated the activation and these mesoporous fibres were fragile. The production technique for this mesoporous carbon was later combined with the technique for making an antibacterial fibre (ref. 34-37) by placing both silver and cobalt in the precursor resin [199]. The mixture of metal appeared to form an alloy. The phenolic resin precursor was also doped with manganese or copper to create a steam-activated metal-containing carbon fibre for use as a deodoriser. Mn-ACF showed good H_2S removal ability [200], but the Cu-ACF was better [201]. Later attempting to make a true mesoporous fibre, without a metal catalyst, the same group combined polymeric precursors, a phenolic resin with poly(vinyl butyral), a polymer that would decompose to only gaseous products upon heating leaving voids [202]. This procedure was said to eliminate the activation step required to create porosity. Many of the pores created however appeared to be closed [203].

18. The Shape of the Pores

Scanning tunnelling microscopy (STM) was used by Economy et al. to help visualise the porous structure of phenolic resin-based fibres [204], where the pores were said to be elongated and oriented parallel to the fibre axis with oval cross sections. Further investigations compared the STM results with gas adsorption and equation fits (Dubinin-Radushkevich-Stoeckli) with surprisingly good results [205] since the fit assumes a slit-shaped pore and ellipsoidal micropores were observed. A new technique was developed to help reduce the cost of the fibres which consisted of coating glass fibres with the activated phenolic resin-based carbon. The resulting composite fibres showed

very fast kinetics of adsorption and desorption [206].

19. Environmental Uses

19.1 Gas Phase Clean-Up

For environmental applications, Mochida et al. looked at PAN-based fibres for NO reduction in ammonia [207 208] and the reduction of NO over various carbon fibres in humid air [209], concluding acid groups on the surface contribute to high activity. The adsorption/desorption of water vapour [210] and the catalytic activity in dehydrochlorination reactions on these fibres was reported in 1995 [211 212]. SO_2 adsorption by heat treated PAN-based fibres and pitch-based fibres [213 214 215 216] was studied by this group [217 218 219 220 221 222] and others [223 224 225 226 227 228 229] while Mangun et al. studied the adsorption of SO_2 on various phenol resin-based fibres [230]. Fuertes and Muniz attributed the higher performance of the PAN-based fibres to nitrogen functionalities on the surface [231]. Mochida et al. attempted to increase the surface nitrogen concentration of a pitch-based carbon fibre by chemical vapour deposition of pyridine. These fibres performed better than both an "as received" fibre and a benzene-treated fibre for the chemisorption of SO_2 [232]. It was determined that a balance between the nitrogen surface groups and the pore volume needed to be established for maximum efficiency. Later these groups studied the adsorption potential of various AFCs with different pore sizes and pore volumes [233] from various precursor materials, including mesophase pitch [234], and further modification of the pores using chemical vapour deposition [235 236 237 238]. Mochida and coworkers also looked at the uptake of radon on various fibres under several conditions [239].

19.2 Adsorption from Solution

The positive aspects of the kinetics of gas adsorption on carbon cloths (mentioned in paragraph one and noted in [240]) were found not to occur in aqueous solution for the adsorption of humid acids [241]. Reference 240 makes mention of adsorbent blocks for better contact between the fluid and fibre. This paper also mentions axial dispersion in packed beds of fibres. Other studies of ACFs for either water or air treatment concluded that the kinetics of adsorption of aromatic compounds from aqueous solution was favourable and VOCs adsorbed well [242] [243] [244]. Le Cloirec et al. investigated filter designs and pressure drops of water through various configurations of cloth layers [245] [246] [247]. Continued studies include the activation of the carbon cloth for aqueous adsorption [248] and the design of a new adsorber with pleated activated carbon fabric and polypropylene layers for air purification [249].

The placement of heavy metals on the fibre surface by adsorption or pre-impregnation continued to be studied. Examples of this included wastewater treatment and the removal of vanadium [250], chromium (VI) [251] [252] and various chelated metal ions [253] from solution using a series of steam activated isotropic petroleum pitch-based fibres [254]. The studies later included the uptake of combined Cr, Cu and Ni ions at differing pH values [255]. Tomizuki et al. removed dilute concentrations of metal ions from solution using activated carbon felt and strings under applied electrical potentials [256] [257] and Glushachenko et al. determined that a carbon felt, modified with copper, was efficient in the electrochemical adsorption of arsenic from solution [258]. Similarly, Jung et al. applied an electrical potential to ACF felt and studied the resulting cobalt uptake from aqueous

solution [259]. Fu et al. looked at the reaction at the activated carbon fibre surface for reduction of various precious metals [260], which later included Pt(IV) [261 262]. Ozaki et al. using the process developed previously (ref. 202), attempted to deposit platinum on the pore walls of the fibre by loading the metal into the polymeric precursor [263 264] and Ryu et al. looked at the structural and mechanical properties of pitch-based carbon fibres which had been prepared from the precursor with silver nitrate added [265].

Polovina et al. looked at a series of surface treated rayon-based carbon cloth samples (Viskoza-Loznica, Yugoslavia). They concluded that a greater amount of surface oxide could be achieved by an iron nitrate treatment when compared to an air, nitric acid or hydrogen peroxide oxidation [266]. However this iron treated fibre had low mechanical properties . The adsorption of cadmium from solution onto the other oxidised fibres resulted in increasing adsorption with increased oxygen group concentration [267] and in a study on the adsorption of both zinc and cadmium ions from solution, an increase was found to occur with increasing pH of solution [268].

Another novel activation technique was developed by Ryu et al. who treated pitch-based carbon fibres with ozone in basic aqueous solutions. These carbon fibres had reported surface areas above 2500 $m^2.g^{-1}$ [269]. The activated fibres were also used for the adsorption of Cr(VI) [270].

19.3 Methane Uptake for Storage

Kaneko et al. continued to look at metal-impregnated carbons and carbon fibres. In further studies they enhanced the adsorption of supercritical methane on the fibre surface by metal oxide dispersions [271]. Petroleum-pitched-based carbon fibres, activated

with either steam and carbon dioxide, were also investigated by others for their methane adsorption capacity [272]. The maximum surface area reported here was 2400 $m^2.g^{-1}$ for a carbon dioxide-activated fibre [273].

20. Present Work

20.1 Specific end uses

The characterization of the micropores and molecular sieving properties of pitched-based carbon fibres continues [274 275 276 277 278 279 280 281]. One such study was reported on fibres from Osaka Gas with surface areas of 2000 $m^2.g^{-1}$ [282]. Kanata et al. added various organic metal compounds to coal tar pitch in an attempt to produce materials for specific end-uses such as impregnated material, raw material for batteries and superior adsorbents [283]. Coal tar pitch-based ACF felts (Osaka Gas) have also been studied for use as supports for palladium catalysts in shape selective, liquid phase hydrogenation of olefinic C6 hydrocarbons [284]. These fibres have also been treated with the standard Whetlerite impregnants, (copper, silver and chromium) along with granular carbons. The resulting impregnated carbon fibres had a lower physical adsorption capacity than the granular equivalent but a higher chemisorption capacity for acid gas [285].

Guillot et al. have looked at the adsorption of ammonia on carbon fibres, proposing an adsorption model with a similar active site association to that of water [286]. Zietek et al. treated activated carbon fibres from viscose cloth with Whetlerite impregnants and tested their adsorptive properties against chloropicrin and cyanogen chloride [287].

20.2 Fibre Composites

Burchell et al. developed a carbon fibre composite with molecular sieving properties [288] [289]. In this open composite the rate of adsorption was said to be close to that of free fibres [290] [291] with reported surface areas above 1200 $m^2.g^{-1}$. These composites also conduct electricity and have been used in the development of a new separation technique termed "voltage swing adsorption" [292] [293] [294] [295]. This ability to desorb gases using electrical current [296] was later exploited in a study of the storage of natural gas on carbon dioxide activated composites [297]. In further studies Kimber et al. explored the use of these monolithic ACF composites for the removal or organics from aqueous solution [298] and from gas streams [299]. The modelling of the breakthrough of butane was compared to granular activated carbon [300]. The separation of methane and carbon dioxide using fibre composites was studied, as was the strength of the composite, both with respect to the degree of activation [301] [302]. While the initial composites had been conventionally activated after production, with steam or carbon dioxide, studies continued that included composites prepared from pre-activated fibres [303] and later a cyclic form of activation [304] of the composites was investigated [305] [306]. It has been suggested by others that a composite or block shape containing ACFs would be useful in CO_2 removal from flue gas [307]. Carbon fibre composites for support of metal catalysts were also a proposed use of these monoliths [308] . Mixed beds of carbon granules and composites have been devised for attaining maximum efficiency in a gas flow system [309] .

20.3 Medical Uses

Carbon fibres investigated for other medical applications, aside from the bacteriological, included composite tablets of carbon fibre, natural clay and binder to adsorb toxins (pesticides, radiotoxins etc.) from the human body [310]. Kalenyuk et al. investigated the use of fibrous carbonaceous material to immobilise microorganisms [311].

21. Novel precursors

Carbon fibres have also been reported that have been produced from Kevlar (p-phenylene terephthalamide) [312 313 314], Nomex [315 316] and Kevlar-based material, with the conclusion that a Kevlar pulp constitutes a suitable feedstock for preparing microporous activated carbon fibres [317]. Jamond et al. determined carbon dioxide activated Kevlar-based carbon fibres contain narrow micropores [318] and Stoeckli et al. confirmed that polyarylamide fibres (Nomex or Kevlar) when carbonised and steam activated contained relatively narrow micropores [319]. These fibres were quite hydrophilic in nature. Bradley et al. report structural differences between chars made from Kevlar and Nomex [320].

Lu et al. reinvestigated polyvinyl alcohol-based fibres, suggesting it as source of material for a larger pore radius carbon fibre [321]. Poly(vinylacetylene) [322] and poly p-phenylene benzobisoxazole (PBO) [323 324] were other polymeric materials explored for the production of carbon fibres. Sano et al. have produced fibres from softwood lignin [325]. Derbyshire et al. have looked at non-conventional pitch materials such as shale oil asphaltenes and other coal liquefaction products [326].

Studies continue on the porous structure of PAN-based fibres [327 328 329] and the kinetics of the adsorption of organics on these fibres [330]. Recent literature includes

activated carbon fibre composites including some of which were made from combinations of PAN fibres and phenolic resins [331] [332]. Modelling of the adsorption of organic compounds from gas streams with activated-carbon-fibre cloth has also been presented [333].

22.Carbon Impregnated Fabrics

Active carbon impregnated fabrics were investigated recently by Rivin and Kendrick [334] [335]. In the latter study both Type III chemical protective foam fabric (MIL-C-4858) and in-house prepared polyester polyurethane foams with active carbon loadings were tested for toxic agents and agent simulant adsorption under various conditions. Breakthrough curves were modelled using a modified Wheeler equation [336]. Fabrics were processed and studied with known fault arrays.

Eloff et al. have measured breakthrough curves for methyl salicylate on textile materials consisting of carbon impregnated polyurethane foam between a polyester/cotton woven cloth [337]. Their study emphasises the humidity effects of testing and questions whether the simulant represents the real chemical.

23. References to Major Investigations of Non-activated Carbon Fibres

Other extensive bodies of work exist in the literature on carbon fibres, mostly unactivated, which includes graphitic carbon fibres and intercalation, including that of M.S. Dresselhaus [338], A. Oberlin [339], D. D. Edie [340], D.D.L. Chung [341], and the volume by Donnet, J-B. and Bansal, R.C.[342].

References

1. "Carbon Fibers, Manufacture, Use and Economy", Journal de Chimie Physique **81**, 711, 1984, Tatsuhana, M., Hirata, M. and Matsui, J.

2. "The Carbonisation of Polyvinyl-alcohol Fibre", Symposium on Carbon, Tokyo, 1964, Carbon Society of Japan, III-7, Shindy, A. and Soma, I.

3. "Electronic Properties of Carbonised Polyacrylonitrile Fibres", Symposium on Carbon, Tokyo, 1964, Carbon Society of Japan, IV-8, Yamaguchi, T.

4. "Carbonisation of Cellulose Fibres - I. Low Temperature Pyrolysis", Carbon **2**, 211, 1964, Tang, M.M. and Bacon, R.

5. "Carbonisation of Cellulose Fibres - II. Physical Property Study", Carbon **2**, 221, 1964, Bacon, R. and Tang, M.M.

6. "Characterization of Surface Reactivity of Graphite Fibre by Solute Adsorption", Carbon **12,** 609, 1974, Brooks, C.S., Golden, G.S. and Scola, D.A..

7. "Preparation and Structure of Saran-Carbon Fibres", Carbon **8,** 597, 1970, Boucher, E.A., Cooper, R.N. and Everett, D.H.

8. "Effect of Heat Treatment on the Morphology and Structure of Crystals, Powders, and Fibres of Polyacrylonitrile and Saran", Journal of Polymer Science: Part A-2, Vol.**10**, 1285, 1972, Boucher, E.A., Langdon, D.J. and Manning, R.J.

9. "Method for Producing Carbon Fibres", United States Patent # 3,903,220, 1975, Economy, J., Lin, R.Y. and Murty, H.N.

10. "The Mesophase and High Modulus Carbon Fibres from Pitch", Carbon **16**, 409, 1977, Singer, L.S.

11. "Process for Producing Carbon Fibres from Mesophase Pitch", United States Patent # 3,976,729, 1976, Lewis, I.C., McHenry, E.R. and Singer, L.S.

12. "Process for Producing Carbon Fibre", United States Patent # 3,917,776, 1975, Sato, H., Takahashi, H., Kaneko, T. and Takemura, T.

13. "Process for the Preparation of Carbon Fibre", United States Patent # 3,972,984, 1976, Iizuki, M., Sugiyama, N. and Hisatomi, Y.

14. "Process for Producing Carbon Fibres", United States Patent # 4,113,847, 1978, Fukushima, K., Kusunose, T. and Nosaka, Y.

15. "Pore Blockage of Activated Charcoal by Latex Sphere and their Effect on Organic Vapour Penetration Rates", Technical Paper No.140, Chemical Defence Establishment, Porton Down, Salisbury, Wilts., Wilkinson, M.C. and Preston, J.C.

16. "Quilted Fabric Containing High Surface Area Carbon Fibres", United States Patent # 3,769,144, 1973, Economy, J.

17. "Laminated, Highly Sorbent, Active Carbon Fabric", United States Patent # 4,217,386, 1980, Arons, G.N. and Macnair, R.N.

18. "Flocked Fabric Laminate for Protection Against Chemical Agents", United States Patent #4,459,332, 1984, Giglia. R.D.

19. "Activated Carbon Fibres and Fabrics", Extended Abstracts 12th Biennial Conference on Carbon, Pittsburgh, Pennsylvania, 1975, p.285, Macnair, R.N., Arons, G.N. and Coffin, L.G.

20. "The Effect of Faults in Activated Carbon Beds on Gas Adsorption Efficiency", Extended Abstracts 12th Biennial Conference on Carbon, Pittsburgh, Pennsylvania, 1975, p.209, Jonas, L.A. and Berlin, H.M.

21. "Investigation of the Adsorption Kinetics of Benzene on Impregnated Polyurethane Foam with Active Carbon", Extended Abstracts Carbon '88, Newcastle upon Tyne. UK, p.277, Bastic, J., Dobricanin, M. and Skala, D.

22. "The Adsorption of Organic and Inorganic Phosphates into a New Activated Carbon Adsorbent", Journal of Colloid and Interface Science, Vol. **86,** 397, 1982, Jayson, G.G., Lawless, T.A. and Fairhurst, D.

23. "Sequential Carbonisation and Activation of Fibrous Material in a Carbon Dioxide Atmosphere", United States Patent # 3,849, 332, 1974, Bailey, A. Maggs, F.A.P. and Williams, J.H., and "Filter Assemblies with Layers of Activated Carbon Fibrous Cloth", United States Patent # 4,234,326, 1980, Bailey, A. and Maggs, F.A.G.

24. For example, "The Influence of Porosity on the Heats of Wetting of Charcoals and Charcoal Cloths", Characterization of Porous Solids (COPS), p.89, Universite de Neuchatel, Switzerland, 1978, Maggs, F.A.P. and Robins, G.A., and "The Use of Adsorptive Filters in Air Purification", Chemical Defence Establishment, Porton Down, Maggs, F.A.P.(year unknown).

25. "Adsorptive Devices", United States Patent # 3,944,403, 1976, Simpson, K. and Maggs, F.A.P.

26. "Physical Adsorption and Heat of Immersion Studies of Microporous Carbons", Carbon **20,** 339, 1981, Atkinson, D., McLeod, A.I., Sing, K.S.W. and Capon, A.

27. "The Adsorption of Low Boiling Point Gases by Activated Charcoal Cloth", Extended Abstracts 15th Biennial Conference on Carbon, p.232, 1981, Capon, A., Alves, B.R., Smith, M.E. and White. M.P.

28. "Copper Sphere Development in Carbonised Viscose Rayon Containing $CuCl_2$", Extended Abstracts 15th Biennial Conference on Carbon, p.258, 1981, Capon, A., Creasey, J.M. and Cox, R.A.

29. "Compensation Effect in the Activation of Fibrous Chars Prepared from Viscose", Carbon **21,** 75, 1983, Capon, A. and Maggs, F.A.P.

30. "Comparison of the Adsorptive Performance of CDE Charcoal Cloth and Granular Charcoal", Extended Abstracts 16th Biennial Conference on Carbon, San Diego, California, 1983, p.323, Smith, M.E. and Davies, J.A.

31. "Activated Carbon", United States Patent # 4,732,805, 1988, Maggs, F.A.P.

32. "Activated Carbon Products and Their Manufacture", United States Patent # 4,529,623, 1985, Maggs, F.A.P.

33. "Activated Carbon Products and Their Manufacture", United States Patent # 4,657,808, 1987, Maggs, F.A.P.

34. "Antibacterial Activated Carbon Fibre Derived from Phenolic Resin Containing Silver Nitrate", Carbon **31**, 71, 1993, Oya, A., Yoshida, S., Abe, Y., Iizuka, T. and Makiyama, N.

35. "Preparation of Pitch-Base Antibacterial Activated Carbon Fibre", Carbon **31**, 1243, 1993, Oya, A., Wakahara, T. and Yoshida, S.

36. "Antibacterial Activated Carbon Fibre Derived from Methacrylate-Grafted Phenolic Resin, Carbon **32**, 107, 1994, Oya, A., Kimura, M., Sugo, T., Katakai, A., Abe, Y., Iizuka, T., Makiyama, N., Linares-Solano, A. .and Salinas-Matinez de Lecea, C.

37. "Preparation and Properties of Antibacterial Activated Carbon Fibre", Extended Abstracts of Carbon'94, Granada, Spain, p.652, Yoshida, S., Oya, A., Iizuka, T., Linares-Solano-A., Salinas-Martinez de Lecea. C., Alcaniz, J. and Cazorla, D.

38. "Antibacterial Pitch-Based Activated Carbon Fibre Supporting Silver", Carbon **36**, 61, 1998, Li, Ch.Y., Wan, Z., Wang, J., Wang, Y.L., Jiang, X.Q. and Han, L.M.

39. "Sorption of Phosphine by Activated Carbon Cloth and the Effects of Impregnation with Silver and Copper Nitrates and the Presence of Water", Carbon **23**, 353, 1985, Hall, P.G., Gittins, P.M., Winn, J.M. and Robertson, J.

40. "Carbon Fibres as Supports for Transitions Metal Catalysts in Hydrocarbon Oxidation Reactions", Carbon **23**, 209, 1985, Ross, R.A., Fairbridge, C. and MacCallum, J.R.

41. "Study of Molecular Sieve Carbons, Part 1- Pore Structure, Gradual Pore Opening and Mechanism of Molecular Sieving", Journal of the Chemical Society, Faraday Transactions I **76**, 2457, 1980, Koresh, J. and Soffer, A.

42. "Study of Molecular Sieve Carbons, Part 2 - Estimation of Cross-Sectional Diameters of Non-Spherical Molecules", Journal of the Chemical Society, Faraday Transactions I **76**, 2472, 1980, Koresh, J. and Soffer, A.

43. "Study of Molecular Sieve Carbons, Part 3 - Adsorption Kinetics According to a Surface-Barrier Model", Journal of the Chemical Society, Faraday Transactions I **77**, 3005, 1981, Koresh, J. and Soffer, A.

44. "Molecular Sieving Range of Pore Diameters of Adsorbents", Journal of the Chemical Society, Faraday Transactions I **76**, 2507, 1980, Koresh, J. and Soffer, A.

45. "Adsorption Interaction of Water with Microporous Adsorbents, Part 1- Water-Vapour Adsorption on Activated Carbon Cloth", Journal of the Chemical Society, Faraday Transactions I **79**, 1147, 1983, Barton, S.S. and Koresh, J.E.

46. "Adsorption Interaction of Water with Microporous Adsorbents, Part 2- Enthalpy of Immersion and Thermal-Desorption Studies", Journal of the Chemical Society, Faraday Transactions I **79**, 1157, 1983, Barton, S.S. and Koresh, J.E.

47. "Adsorption Interaction of Water with Microporous Adsorbents, Part 3 - Dependence of Adsorption-Desorption Hystereses on Extent of Activation", Journal of the Chemical Society, Faraday Transactions I **79**, 1165, 1983, Barton, S.S. and Koresh, J.E.

48. "Development of Pore Structure in Carbon Cloth by HNO_3 Activation", Journal of the Chemical Society, Faraday Transactions I **79**, 1173, 1983, and Extended Abstracts 16th Biennial Conference on Carbon, San Diego, California, 1983, p.355, Barton, S.S. and Koresh, J.E.

49. "A Study of the Surface Oxides on Carbon Cloth by Electrical Conductivity", Carbon **22**, 481, 1984, Barton, S.S. and Koresh, J.E.

50. "Plasma Activation of Carbon Cloth", Carbon **24**, 325, 1986, Inspector, A., Koresh, J.E., Barton S.S. and Evans, M.J.B.

51. "The Effect of Chlorination on the Adsorptive Properties of Water on Carbon Cloth", Carbon **25**, 663, 1987, Barton, S.S., Evans, M.J.B., Koresh, J.E. and Tobias, H.

52. "Adsorptive Properties of Microporous Carbons: Primary and Secondary Micropore Filling" Extended Abstracts International Carbon Conference, Bordeaux, France, 1984, p.16, and Journal de Chimie Physique, **81**, 791, 1984, Atkinson, D., McLeod, A.I. and Sing, K.S.W.

53. "A Study of the Micropore Structure of Carbonized Rayon Yarn by Nitrogen Adsorption and Nonane Pre-adsorption", Adsorption Science and Technology **2**, 89, 1985, Bohra, J.N. and Sing, K.S.W.

54. "Microporosity in Rayon-Based Carbonised and Activated Carbon Fibres", Colloids and Surfaces **58**, 375, 1991, Bohra, J.N. and Saxena, R.K.

55. "Assessment of Microporous Structure of Fibrous Carbon Adsorbents", Extended Abstracts Carbon '88, Newcastle upon Tyne, U.K., p.501, Polovina, M. and McEnaney, B.

56. "Adsorption of Volatile Substances on Activated Carbon Fibres", Proceedings of the XVIIIth Biennial Carbon Conference on Carbon, Worcester, Mass., 1987, p.110, Sakoda, A., Kawazoe, K. and Suzuki, M.

57. "Micro- and Meso-Porosity in Carbon Fabrics", Proceedings of the XVIIIth Biennial Carbon Conference on Carbon, Worcester, Mass., 1987, p.96, Ismail, I.M.K.

58. "Microporosity of Carbon Fibres and Saran Chars", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.30, Ismail, I.M.K.

59. "Effect of Reactive Atmosphere and Maximum Heat Treatment Temperature on Char Characteristics of Pyrolysed Rayon Cloth", Carbon **35**, 703, 1997, Kumar, K., Kothari, R. and Bohra, J.N.

60. "Correlation Between Adsorption and X-Ray Diffraction Studies on Viscose Rayon Based Activated Carbon Cloth", Carbon **35**, 1842, 1997, Kumar, K., Saxena, R.K., Kothari, R., Suri, D.K., Kaushik, N.K. and Bohra, J.N.

61. "Characterization of Activated Carbon Fibres by Small Angle X-Ray Scattering", Carbon **36**, 309, 1998, Cazorla-Amoros, D., Salinas-Martinez de Lecea, C., Gardner, M., North, A. and Dore, J.

62. "Adsorption Characteristics of Activated Pitch-Based Carbon Fibres", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.96, Rhu, S.K., Rhee, J.K., Lee, D.W., Pusset, N. and Ehrburger, P.

63. "TEM Study of Pitch-Based Activated Carbon Fibres", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.286, Rhu, S.-K., Jin, H.-K., Rhee, B.-S. and Endo, M.

64. "Studies on Pitch-Based Activated Carbon Fibres", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.288, Li, Y., Shen, Z. and Zhang, C.M.

65. "Study on Activation Kinetics of Pitch-Based Carbon Fibres", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.456, Liu, C., Liu, L. and Qian, S..

66. "Adsorption Properties of Pitch-Based Activated Carbon Fibres", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.102, Liu, C., Liu, L. and Qian, S.

67. "Study on the Adsorption Behaviour of Pitched -based Activated Carbon Fibre to Noble Metal Ion", Extended Abstracts for the International Carbon Conference, Paris, France 1990, p.126, Ling, L.C., Sun, Y.H., Liu, L. Wang, M.Z. and Qian, S.A.

68. "Crystalline Structure and Properties of PEEK Around Carbon Fibre", Extended Abstracts for the International Carbon Conference, Paris, France 1990, p.176, Zhang, Z. and Zeng, H.

69. "Recent Progress on the Preparation, Structure and Properties of Activated Carbon Fibres in Our Institute", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.172, Zeng, H and Fu, R.

70. "Studies on the Redox Kinetics of Activated Carbon Fibre", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.174, Zeng, H and Fu, R.

71. "X-Ray Photoelectron Spectroscopy Studies of Activated Carbon Fibre Surface"Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.206, Fu, R. and Zeng, H.

72. "Studies on the Redox Mechanism of Activated Carbon Fibre by X-Ray Photoelectron Spectroscopy", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.208, Fu, R. and Zeng, H.

73. "Studies on the Redox Characteristics of Activated Carbon Fibres", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.210, Fu, R., Zeng, H and Wu, B.

74. "Studies on the Relationship between the Redox Property and Physical Adsorption of Activated Carbon Fibres", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.212, Fu, R. and Zeng, H.

75. "Study on Adsorption Mechanism of Dye on Activated Carbon Fibre", Extended Abstracts of Carbon'94, Granada, Spain, p.384, Yaoting, C., Youwei, G. and Xuemei, L.

76. "Treatment of Basic Dye Wastes with Activated Carbon Fabrics", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.524, Ko, T.-H.

77. "X-Ray Photoelectron Spectroscopic Studies of Carbon Fibre Surfaces II - The Effect of Electrochemical Treatment", Carbon **21,** 53, 1983, Proctor, A. and Sherwood, P.M.A.

78. "X-Ray Photoelectron Spectroscopic Studies of Carbon Fibre Surfaces Part 4- The Effect of Treatment in Nitric Acid", Journal of the Chemical Society, Faraday Transactions I, **80**, 2099, 1984, Kozlowski, C. and Sherwood, P.M.A.

79. "X-Ray Photoelectron Spectroscopic Studies of Carbon Fibre Surfaces VII- Electrochemical Treatment in Ammonium Salt Electrolytes", Carbon **24,** 357, 1986, Kozlowski, C. and Sherwood, P.M.A.

80. "Reduced Pressure Sublimation of Amine Compounds on Activated Carbons", United States Patent # 5,145,820, 1992, Liang, S.H. and Harrison, B.H.

81. "Organic Amine Impregnated Active Carbon", United States Patent # 5,462,908, 1995, Liang, S.H. , Harrison, B.H. and Pagotto, J.

82. "Method and Apparatus for Removing Cyanogen Chloride from Air", United States Patent # 4,802,898, 1989, Tolles, E.

83. "Method and Apparatus for Removing Hydrogen Cyanide, Cyanogen and Cyanogen Chloride from Air", United States Patent # 4,801,311, 1989, Tolles, E.D.

84. "Chromium-Free Impregnated Activated Carbon for Adsorption of Toxic Gases and/or Vapours", United States Patent # 5,063,196, 1991, Doughty, D.T.

85. "Method and Apparatus for Manufacturing TEDA-Impregnated Active Carbon in Fluidized Bed Type Absorbing Tower By Generating TEDA Vapour by Means of Hot Air", United States patent # 5,792,720, 1998, Ro, S.-G. and Lee, H.-K.

86. "Determination of the Acidity of Carbon-Fibre Surfaces by Means of X-Ray Photoelectron Spectroscopy Adsorption Isotherms", Journal of Material Chemistry **2**, 939, 1992, Baille, C.A., Watts, J.F. and Castle, J.E.

87. "Carbon Based Composites", Journal de Chimie Physique **81**, 715, 1984, Fritzer, E.

88. "Characterization of Carbon-Carbon Composites II- Oxidation Behaviour", Carbon **19,** 7, 1981, Ehrburger, P., Lahaye, J. and Bourgeois, C.

89. "Borate Treatment of Carbon Fibres and Carbon/Carbon Composites for Improved Oxidation Resistence", Carbon **24,** 737, 1986, McKee, D.W.

90. "Studies of Activated Charcoal Cloth. II. The Influence of Boron-Containing Impregnates on the Rate of Activation in Carbon Dioxide Gas", Carbon **25**, 565, 1987, Freeman, J.J. and Gimblett, F.G.R.

91."Studies of Activated Charcoal Cloth. IV. Influence of Phosphate Impregnates on the Rate of Activation in Carbon Dioxide Gas", Carbon **26**, 501, 1988, Freeman, J.J. and Gimblett, F.G.R.

92. "Studies of Activated Charcoal Cloth, III. Mesopore Development Induced by Phosphate Impregnants", Carbon **26**, 7, 1988, Freeman, J.J., Gimblett, F.G.R., Roberts, R.A. and Sing, K.S.W.

93."Activation of Phosphate-Impregnated Charcoal Cloths in Carbon Dioxide Gas at 850°C", Carbon **26**, 589, 1988, Freeman, J.J. and Gimblett, F.G.R.

94. "The Development of Mesoporosity in Activated Carbon Cloth", Extended Abstracts for the Nineteenth Biennial Conference on Carbon, Penn State, PA., 1989, p.4, Freeman, J.J., Gimblett, F.G.R., Coney, N.J., Sharpe, J.R., Reynolds, A.J. and Sing, K.S.W.

95. "Further Studies of the Development of Mesopore Structure in Activated Carbon Cloth", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.60, Freeman, J.J., Reynolds, A.J., Sing, K.S.W. and Zuurbier, R.J.

96. "The Control of Porosity in Activated Carbon Cloth", Extended Abstracts Carbon '88, Newcastle upon Tyne, U.K., p.510, Freeman, J.J., Gimblett, F.G.R., Sing, K.S.W. and Wright. J.E.

97."Studies of Activated Charcoal Cloth, V. Modification of Pore Structure by Impregnation with Certain Transition Metal Salts and Oxo-Complexes", Carbon **27**, 85, 1989, Freeman, J.J., Gimblett, F.G.R., and Sing, K.S.W.

98. "Pore Structure in Activated Viscose Rayon Chars Pre-Treated with Transition Metal Compounds", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.22, Freeman, J.J., Kent, R.J., Reynolds, A.J., Sing, K.S.W. and Tomlinson, J.B.

99. "Carbon Cloth Preparation for Chemisorption", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.90, Polovina, M. and Djuricic, L.

100. "Adsorption of Molecules with Different Polarity on Activated Carbon Cloth", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.476, Polovina, M. and Stojanovic, B.

101. "Modification of Carbonised PAN by $FeCl_2$ and $CoCl_2$", Extended Abstracts of Carbon'94, Granada, Spain, p.182, Morawski, A.W. Kalucki, K., Nakashima, M. and Ingaki, M.

102. Transition Metal-Doped carbon Fibrous Materials: Preparation, Characterization, and Dehydrogenation Activity", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.204, Kryazhev, Y.G., Petrov, I.Y., Khokhlova, G.P. and Patrakov, Y.F.

103. "Adsorption of Toxic Gases by Impregnated Activated Charcoal Cloth", Abstracts for 5th Conference on Surface and Colloid Science, Potsdam N.Y., 1985, #164, Jayson, G.G., Thompson, G., Mile, B., Sangster, J., Brown, N. and Wilkinson, M.C.

104. "Adsorption Characteristics of Impregnated Activated Charcoal Cloth for Hydrogen Cyanide", Journal of Colloid and Interface Science **116**, 211, 1987, Brown, P.N., Jayson, G.G., Thompson, G. and Wilkinson, M.C.

105. "Adsorption Studies of Chromium Ions on Activated Charcoal Cloth", Extended Abstracts Carbon '88, Newcastle upon Tyne, U.K., p.10, Jayson, G.G., Sangster, J.A., Thompson, G. and Wilkinson, M.C.

106. "The Adsorption of Hydrogen Cyanide by Impregnated Activated Carbon Cloth. Part 1: Studies on Cobalt and Nickel Acetates as Impregnants for Hydrogen Cyanide Removal", Carbon **26,** 701, 1988, Alder, J.F., Fielden, P.R. and Smith, S.J.

107. "The Adsorption of Hydrogen Cyanide by Impregnated Activated Carbon Cloth. Part II: Reactivity of Impregnated Metal Carboxylates Towards Hydrogen Cyanide", Carbon **26,** 713, 1988, Alder, J.F., Fielden, P.R. and Smith, S.J.

108. "Reactions of Hydrogen Cyanide with Activated Charcoals Impregnated with Copper and Chromium", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.42, Brown, P.N., Jayson, G.G., Thompson, G. and Wilkinson, M.C.

109. " Activated Charcoal Cloth as a "Support" for Copper in the Decomposition of Formic Acid", Carbon **27**, 171, 1989, Brown, P.N., Jayson, G.G., Mile, B. and Wilkinson, M.C.

110. "Adsorption of Chromium from Aqueous Solution onto Activated Charcoal Cloth", Carbon **31,** 487, 1993, Jayson, G.G., Sangster, J.A., Thompson, G. and Wilkinson, M.C.

111. "Stoichiometric Analysis of Chemisorption of Hydrogen-Cyanide onto Activated Carbon Cloth", Carbon **33,** 1433, 1995, Rajakovic, L.V., Iliac, M.R., Jovanic, P.B. and Radosevic, P.B.

112. "Identification of Surface Groups Responsible for Amine Adsorption on Active Charcoal Cloth - A Comparative Study by XPS and FTIR Spectroscopy", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.408. Sandle, N.K. and Varghese, F.V.

113. "Production of High Surface Area Carbon Fibres" United States Patent # 4,946,663, 1990, Audley, G.J. and Grint, A.

114. "The Preparation and Characterization of KOH Activated Carbonised Viscose Rayon Charcoal Cloth", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.32, Audley, G.J., Howes, R.J. and Jessop, C.A..

115. "Active Carbons for Natural Gas Storage", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.490, Lewis, I.C., Greinke, R.A. and Strong, S.L.

116. "Preparation of PAN-Based Activated Carbon Fibre", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.441, Kim, J.-Y., Hong, I., Lee, J.G. and Lee, G.D.

117. "Activated Carbon Fibres from PAN. I. Steam and KOH Activation", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.120, Martin-Gullon, I., Jagtoyen, M. and Derbyshire, F.

118. "Pitch-Based Activated Carbon Fibres Containing K_2CO_3 as Catalysts: Autocondensation of Cyclohexanone", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.212, Przepiorski, J., Oya, A., Abe, Y., Lopez-Peinado, A.J. and Martin-Aranda, R.M.

119. "Potassium-Loaded ACF Against H_2S Gas by Blending and Dipping Method: Effect of Subsequent Deodorizations and Regenerations on Deodorant Ability", Extended Abstracts for Eurocarbon '98, p.145, Strasbourg, France, 1998, Przepiorski, J., Ozaki, J. and Oya, A.

120. "Sorbent Internally Ribbed Carbon-Containing Material and Protective Garment Fabricated Therefrom", United States Patent # 4,513,047, 1985, Leach, J. and Davis, D.A.

121. "Laminated Fabric for Protective Clothing", United States Patent # 4,869,947, 1989, Kirayoglu, B.

122. "Non-woven Activated Carbon Fabric", United States Patent # 4,565,727, 1986, Giglia, R.D. and Battistelli, E.A.

123. "Protective Clothing Material", United States Patent, # 5,024,594, 1991, Athayde, A.L. and Baker, R.W.

124. "CBW Protective Clothing", United States Patent, # 5,1112,666, 1992, Langston, R.D.

125. "Composite Protective Materials, their Production and Articles Made Thereof", United States Patent, # 5,162,398, 1992, Katz, M.

126. "Reduced-Stress Vapour Sorptive Garments", United States Patent # 4,433,924, 1984, Eian, G.

127. "Waterproof and Moisture-conducting Fabric Coated with Hydrophilic Polymer", United States Patent # 4,454,191, 1984,

128. "Waterproof and Air-Tight, Moisture-conducting Textile Material", United States Patent # 4,554,198, 1985, von Blucher, H, von Blucher, H. and de Ruiter, E.

129. "Adsorption Material Comprising Activated Carbon Fibre and Polytetrafluoroethylene"' European Patent, Ep0661094, 1995, Sakai Naoki, Shigei Tetsuro and Tanaka Takayuki

130. "Gas Resistant Foam Materials", United States Patent # 4,046,939, 1977, Hart, J.A.H.

131. "Chemical Protective Fabric", United States Patent # 5,614,301, 1997, Katz, M.

132. "The Effect of Full Sinusoidal Flow on the Lifetime of Carbon Cloth Filters", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.484, Audley, G.J., Bailey, A. and Williams, M.R.

133. "The Electrical Conductivity of Activated Charcoal Cloth (ACC)", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.751, Grint, A., Johnson, I.P., Bailey, A. and Williams, M.R.

134. "Cyclic Voltametric Studies of Heat Treated and Oxidised Carbon Fibres in Organic and Aqueous Solutions", Monatshefte fur Chemie **125**, 1365, 1994, Biniak, S., Pakula, M. and Swiatkowski, A.

135. "The Electrochemical Behaviour of Carbon Fibre Electrodes in Various Electrolytes. Double Layer Capacitance", Carbon **33**, 1255, 1995, Biniak, S., Dzielendziak, B. and Siedlewski, J.

136. "Chemical Modification of Carbon Fibre Surfaces by Nitric Acid Oxidation Followed by Reaction with Tetraethylenepentamine", Carbon **35**, 317, 1997, Pittman Jr, C.U., He, G.-R., Wu, B. and Garder, S.D.

137. "Reactivities of Amine Functions Grafted to Carbon Fibre Surfaces by Tetraethylenepentamine. Designing Interfacial Bonding", Carbon **35**, 929, 1997, Pittman, Jr., C.U., Wu. Z., Jiang, W., He, G.-R., Wu,

B., Li, W. and Gardner, S.D.

138. "Modification of Carbon Fibre Surfaces by Electrochemical Reduction of Aryl Diazonium Salts: Application to Carbon Epoxy Composites", Carbon **35,** 801, 1997, Delamar, M., Desarmot, G., Fagebaume, O., Hitmi, R., Pinson, J. and Saveant, J.-M.

139. "Effect of Concentration of Surface Acidic Functional Groups on Electrical Double-Layer Properties of Activated Carbon Fibres", Carbon **28**, 611, 1990, Yoshida, A., Tanahashi, I. and Nishino, A.

140. "Characterization of Activated Carbon Fibre Cloths for Electric Double-Layer Capacitors by Adsorption Method", Carbon **29**, 1033, 1991, Tanahashi, I., Yoshida, A. and Nishino, A.

141. "Activated Carbon Fibre Sheets as Polarizable Electric Double Layer Capacitors", Carbon **28**, 477, 1990, Tanahashi, I., Yoshida, A. and Nishino, A.

142. "The Reduction Property of Activated Carbon Fibres", Carbon **31**, 1089, 1993, Fu, U., Zeng, H. and Lu, Y.

143. "Li Secondary Battery and Electrical Double Layer Capacitor with Carbon Fibre Electrodes", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.654, Endo, M., Okada, Y., Nakamura, H., Ishida, S. and Inagaki, M.

144. "Evolution of Micropore Structure of Activated Charcoal Cloth", Carbon **29,** 499, 1991, Carrott, P.J.M. and Freeman, J.J.

145. "Adsorption of Methanol and Water by Charcoal Cloth", Proceedings of The Characterization of Porous Solids (COPS II), Alicante, Spain, 1990, p.341, Goncalves da Silva, A.M., Ribeiro Carrott, M.M.L., Carrott, P.J.M. and Brotas de Carvalho, M.M.

146. "Boron Trifluoride Initiated Polymerisation of Isobutene in the Micropores of Activated Charcoal Cloth", Carbon **29,** 507, 1991, Carrott, P.J.M.

147. "Deposition of Ethylene Oxide on Activated Charcoal Cloth", Proceedings of Carbon '92, Essen, Germany, 1992, p.400, Carrott, P.J.M. and Robeiro Carrott, M.M.L.

148. "Evaluation of Energetic Heterogeneity and Microporosity of Activated Carbon Fibres on the Basis of Gas Adsorption Isotherms", Langmuir **7**, 2719, 1991, Jaroniec, M., Gilpin, R.K., Kaneko, K. and Choma, J.

149. "Multi-Stage Micropore Filling of N_2 and Ar by Microporous Carbon Fibres", The Proceedings of The Characterization of Porous Carbons (COPS II), Alicante, Spain, 1990, p.429, Kakei, K., Ozeki, S., Suzuki, T. and Kaneko, K.

150. "Anomalous Micropore Filling of NO on Fe_2O_3 - Dispersed Activated Carbon Fibres", Proceedings of the Characterization of Porous Solids, (COPS 1), p.183, 1987, Kaneko, K.

151. "Anomalous Micropore Filling of NO on α–FeOOH-Dispersed Activated Carbon Fibres", Langmuir **3**, 357, 1987, Kaneko, K.

152. "Structural Change of Activated Carbon Fibres with Desorption by in Situ X-Ray Diffraction", Carbon **26**, 743, 1988, Suzuki, T. and Kaneko, K.

153. "Molecular Resolution Analysis of α-FeOOH -Dispersed Activated Carbon Fibres", Langmuir **7**, 109, 1991, Kaneko, K.

154. "Adsorption of NO_2 on Activated Carbon Fibres", Carbon **27**, 954, 1989, Kaneko, K. and Imai, J.

155. "Clathrate Formation of NO with H_2O in Micropores of Activated Carbon Fibres", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.150, Kaneko, K., Fujie, K. and Suzuki, T.

156. "Accelerating Reaction Field Effects of Slit-Shaped Micropores of Activated Carbon Fibres for NO_x - SO_2 Reaction", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.80, Imai, J., Souma, M., Ozeki, S., Suzuki, T.A and Kaneko, K.

157. "Dynamic NO_3^- Adsorption Characteristics of Iron Oxide-Dispersed Activated Carbon Fibres", Carbon **29**, 1287, 1991, Kaneko, K., Camera, S., Ozecki, S. and Souma, M.

158. "Micropore Filling of Supercritical NO on Cu-doped Iron Oxide Dispersed Activated Carbon Fibres", Journal of Colloid and Interface Science **142**, 489, 1991, Kaneko, K., Wang, Z., Suzuki, T.,Ozeki, S., Kosugi, N. and Kuroda, H.

159. "Chemisorption - Assisted Micropore Filling of NO on Surface-Modified Activated Carbon Fibres", Third International Conference on Fundamentals of Adsorption, Sonthifen, Germany , 1989, p.355, Kaneko, K., Yamamoto, H., Suzuki, T. and Ozaki, S.

160. "Mixed Valence Oxide-Dispersion -Induced Micropore Filling of Supercritical NO", The Journal of Physical Chemistry **96**, 10917, 1992, Wang, Z-M., Suzuki, T., Uekawa, N., Asakura, K. and Kaneko, K.

161. "N_2 Formation from NO Over Pt-Electrodeposited Activated Carbon Fibre", Carbon **32**, 1186, 1994, Li, G.X., Nishi, Y., Ozeki, S. and Kaneko, K.

162. "Ultramicropores in Microporous Carbon Fibres evidenced by Helium Adsorption at 4.2 K"., Journal of the Chemical Society, Faraday Transactions **87**, 1915, 1991, Kuwabara, H., Suzuki, T. and Kaneko, K..

163. "Micropore Geometry Determination of Activated Carbon Fibres by Small Angle X-Ray Scattering", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.422, Ruike, M., Kasu, T., Suzuki, T and Kaneko, K.

164. "Microporosity and Adsorption Characteristics Against NO, SO_2 and NH_3 of Pitch-based Activated Carbon Fibres", Carbon **26**, 317,1988, Kaneko, K., Nakahigashi, Y. and Nagata, K.

165. "Effect of α-FeOOH Dispersion on Adsorption Characteristics of Pitched-based Activated Carbon Fibres Against NO, SO_2, and NH_3, Carbon **27**, 815, 1989, Kaneko, K. and Shindo, N.

166. "Phase Transitcn of SO_2 Molecules in a Carbon Micropore", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.426, Wang, Z.-M. and Kaneko, K.

167. "Enhancement of NO Adsorption on Pitch-Based Activated Carbon Fibres by Dispersion of Cu-Doped α–FeOOH Fine Particles, Carbon **32**, 515, 1994, Wang, Z.-M., Shindo, N., Otake, Y. and Kaneko, K.

168. "NO Reduction Over Ru-Tailored Activated Carbon Fibers at Ambient Temperature", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.394, Nishi, Y., Suzuki, T. and Kaneko, K.

169. "NO Reduction over Ultrafine Metal-Tailored Porous Carbon at Ambient Temperature", Extended Abstracts for Eurocarbon '98, p.65, Strasbourg, France, 1998, Nishi, Y., Suzuki, T. and Kaneko, K.

170. "Origin of Superhigh Surface Area and Microcrystalline Graphitic Structures of Activated Carbons", Carbon **30,** 1075, 1992, Kaneko, K., Ishii, C., Ruike, M. and Kuwabara, H.

171. "The Micropore Swelling of Activated Carbon Fibres with Water Adsorption Studied by Use of in Situ Small Angle X-Ray Scattering", Journal of Colloid and Interface Science **127**, 298, 1989, Kaneko, K., Fujiwara, Y. and Nishikawa, K.

172. "Microcrystalline Graphic-Structure and Microporosity of Adsorbent Carbon", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.18, 1991, Kaneko, K.

173. "Structural Characterization of Heat-treated Activated Carbon Fibres", Journal of Porous Materials **4**, 181, 1997, Ishii, C., Suzuki, T., Shindo, N. and Kaneko, K.

174. "Water Rejective Nature of Fluorinated Microporous Carbon Fibres", Langmuir **11**, 716, 1995, Li, G., Kaneko, K., Ozeki, S., Okino, F., Ishikawa, R., Kanda, M. and Touhara, H.

175. "'Pore Structure and Adsorption Properties of Microporous Carbon-Alloyed Fibre", Extended Abstracts for Eurocarbon '98, p.53, Strasbourg, France, 1998, Kaneko, K., Setoyama, N., Li, G., Nishikawa, H., Okino, F., Ishikawa, T., Kanda, M. and Touhara, H.

176. "Adsorption Behaviour of Polar Molecules in Fluorinated Micropores", Journal of Colloid and Interface Science **172**, 539, 1995, Li, G., Kaneko, K., Okino, F., Touhara, H., Ishikawa, R. and Kanda, M.

177. "Nitrogen Adsorption on Fluorinated Activated Carbon Fibre", Adsorption **2**, 293, 1996, Setoyama, N., Li, G., Kaneko, K., Okino, F., Ishikawa, R., Kanda, M. and Touhara, H.

178. "Process for the Production of Carbon Fibres" United States Patent # 5,063,042, 1991, Arita, Y., Iizuka, T., Abe, Y., Nakamura, Y., Takigami, S. and Takogami, M.

179. "The Effects of Activation by Carbon Dioxide on the Mechanical Properties and Structure of Pan-Based Activated Carbon Fibres", Carbon **30,** 647, 1992, Ko, T.-H., Chiranairadul, P., Lu, C.-K. and Lin, C.-H.

180. "Transmission Electron Microscopy of Steam Activated Viscose Rayon Chars" Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.28, Tomlinson, J.B. and Theocharis, C.B.

181. "Studies of Steam-Activated Viscose Rayon Chars", Carbon **30**, 907, 1992, Tomlinson, J.B., and Theocharis, C.R.

182. "A Comparison of Carbon Dioxide and Steam as Activating Gases for Viscose Rayon Chars", Extended Abstracts for the International Carbon Conference, Paris, France, 1990, p.164. Freeman, J.J., Sing, K.S.W. and Tomlinson, J.B.

183. "The Preparation and Adsorptive Properties of Ammonia-Activated Viscose Rayon Chars", Carbon **31**, 13, 1993, Tomlinson, J.B., Freeman, J.J. and Theocharis, C.R.

184. "Activation of Carbon Fibres by Steam and Carbon Dioxide", Carbon **31,** 841, 1993, Ryu, S.K., Jin, H., Gondy, D., Pusset, B. and Ehrburger, P.

185. "Characteristic Comparison of PAN- and Pitch-Based Carbon Fibres Activated with Carbon Dioxide", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.530, Park, B.B., Lee, Y.S., Shim, H.B., Ryu, S.K. and Rhee, B.S.

186. "Effect of Activating Gas on Tensile Strength and Pore Structure of Pitch-Based Carbon Fibres", Carbon **32,** 1277, 1994, Alcaniz-Monge, J., Cazorla-Amoros, D., Linares-Solano, A., Yoshida, S. and Oya, A.

187. "Porous Texture and Tensile Strength of Activated Carbon Fibres", Extended Abstracts of Carbon'94, Granada, Spain, p.660, Alcaniz-Monge, J., Cazorla-Amoros, D., Linares-Solano, A., Yoshida, S. and Oya, A.

188. "External and Internal Gasification of Pitch-Based Carbon Fibres", Carbon **34,** 808, 1996, Ryu, S.K., Ko, K.R., Gondy, D. and Ehrburger, P.

189. "Production of Activated Carbons: Use of CO_2 versus H_2O as Activating Agent", Carbon **34**, 1297, 1996, Walker, Jr., P.L.

190. "Production of Activated Carbons: Use of CO_2 Versus H_2O as Activating Agent. A Reply to a Letter from P.L.Walker, Jr.", Carbon **35**, 1665, 1997, Alcaniz-Monge, J., Cazorla-Amoros, D. and Linares-Solano, A.

191. "Gasification of Carbon Fibres in Steam", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.284, Sigrist, S., Vix-Guterl, C. and Ehrburger, P.

192. "Dimensional Change of Isotropic Pitch-Based Fibre During Activation", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.506, Gondy, D., Edie, D.D. and Ehrburger, P.

193. "Swelling of Pitch-Based Carbon Fibres During Activation in Carbon Dioxide", Carbon **35**, 1745, 1997, Gondy, D. and Ehrburger, P.

194. "Change on Porosity and Active Surface Area During Activation-Effect of Precursor", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p. 19, 1991, Ehrburger, P., Pusset, N. and Dziedzinl, P.

195. "Modelling the Gasification of Carbon Fibres", Carbon **34**, 223, 1996, Fuertes, A.B., Marban, G. and Muniz, J.

196. "A Comparative Study on Activation Rate of Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.512, Fei, Y.Q. and Derbyshire, F.

197. "Effect of Platinum on Textural Properties of Carbon Fibres upon Activation", Extended Abstracts of Carbon'94, Granada, Spain, p.724, Macias Perez, C., Oya, A., Cazorla-Amoros, D., Linares-Solano, A., and Salina Martinez de Lecea, C.

198. "Formation of Mesopores in Phenolic Resin-Derived Carbon Fiber by Catalytic Activation Using Cobalt", Carbon **33**, 1085, 1995, Oya, A., Yoshida, S., Alcaniz-Monge, J. and Linares-Solano, A.,

199. "Preparation and Properties on an Antibacterial Activated Carbon Fibre Containing Mesopores" Carbon **34**, 53, 1996, Oya, A., Yoshida, S., Alcaniz-Monge, J. and Linares-Solano, A.

200. "Preparation and Evaluation of Deodorant Activated Carbon Fibre", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.522, Nakahara, M., Abe, Y., Oya, A., Imamura, R., Cazorla-Amoros, D. and Salinas-Matinez de Lecea.

201. "Preparation and Properties of Deodorant Activated Carbon Fibre Containing Copper", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.62, Abe, Y., Oya, A, Yoshida, S.Y. and Iizuka, T.

202. " Novel Preparation Method for the Production of Mesoporous Carbon Fiber from a Polymer Blend", Carbon **35,** 1031, 1997, Ozaki, J, Endo, N., Ohizumi, W., Igarashi, K., Nakahara, M., Oya, A., Yoshida, S. and Iizuki, T.

203. "Carbonization of Phenolic Polymer/Poly(Vinyl Butral) Polymer Blend to Prepare Porous Carbon Fibre", Extended Abstracts for Eurocarbon '98, p.X.11, Strasbourg, France, 1998, Satoh, F., Ohizumi, W., Shiraishi, S., Ozaki, J.-I. And Oya, A.

204. "Elucidating the Pore Structure of Activated Carbon Fibres Through Direct Imaging Using Scanning Tunnelling Microscopy (STM)", Carbon **33,** 344, 1995, Economy, J., Daley, M., Hippo, E.A. and Tandon, D.

205. "Elucidating the Porous Structure of Activated Carbon Fibre Using Direct and Indirect Methods", Carbon, **34**, 1191, 1996, Daley, M.A., Tandon, D., Economy, J. and Hippo, E.J.

206. "A Low Cost Approach to Activated Carbon Fibres", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.42, 1997, Economy, J. and Mangun, C.

207. "Catalytic Activities of Active Carbons for Reduction of Nitric Oxide with Ammonia", Proceedings of the XVIIIth Biennial Carbon Conference on Carbon, Worcester, Mass., 1987, p.84, Mochida, I., Fujitsu, H., Shiraishi, I. and Ida, S.

208. "Reactivity of Ammonia on ACF at Ambient Temperature", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.76, Kawano, S., Mochida, I. and Maeda, T.

209. "Reduction of Low Concentration of NO with NH_3 Over Pitch Based Active Carbon Fibre in Humid Air at Ambient Temperature", Carbon **32,** 175, 1994, Mochida, I., Kawano, S., Kisamori, S., Fujitsu, H. and Maeda, T.

210. "Adsorption and Desorption of H_2O Over Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.528, Kawabuchi, Y., Kawano, S. and Mochida, I.

211. "Catalytic Dehydrochlorination of 1,2-Dichloroethane into Vinyl Chloride over PAN-ACF", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.560, Mochida, I., Sotowa, C., Watanabe, Y. and Yatsunami, S.

212. "Catalytic Activity of Surface Modified PAN-ACF for the Dehydrochlorination of 1,2-Dichloroethane", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.566, Mochida, I., Sotowa, C., Watanabe, Y. and Yatsunami, S.

213. "The Ability of Pitch-Based Activated Carbon Fibre to Remove SO_2", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.576, Mochida, I., Kuroda, K., Kawabuchi, Y. and Kawano, S.

214. "De SO_2 and De NO_2 at Room Temperature Over Activated Carbon Fibre", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.10, 1995, Mochida, I., Kawabuchi, Y., Kawano, S., Kuroda, K., Hironaka, M., Matsumura, Y. and Yoshikawa, M.

215. "An Overview on SO_x and NO_x Removal Over Active Carbon Fibres", Abstracts Carbon Material for the Environment , American Carbon Society Workshop, Charleston S.C. p.42, 1996, Mochida, I., Kuroda, K., Kawano, S., Korai, Y., Yasutake, A., Matsumura, Y. and Yoshikawa, M.

216. "Removal of SO_2 over Pitch-based Active Fibres at 50-70°C, "Extended Abstracts for Eurocarbon '98, p.575, Strasbourg, France, 1998, Miyamoto, S., Kawano, S., Korai, Y. and Mochida, I.

217. "Adsorptive Removal of SO_2 in Flue Gas by ACF", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.82, Kisamori, S., Kawano, S. and Mochida, I.

218. "High and Stable de-SO_2 Activity of Lightly Activated PAN-ACF's", Proceedings of Carbon '92, Essen, Germany, 1992, p296, Mochida, I., Kisamori, S. and Fujitsu, H.

219. "Activity Determining Factors of PAN-ACF for SO_2 Removal", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.424, Kisamori, S., Mochida, I. and Kawano, S.

220. "Continuous Removal of SO_2 in the Model Flue Gas Over PAN-ACF Recovering Aquatic H_2SO_4", Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.478, Kisamori, S., Mochida, I. and Kawano, S.

221. "Oxidative Removal of SO_2 with Recovering H_2SO_4 and Oxidation of NO into NO_2 Over Activated Carbon Fibre at Room Temperature", Extended Abstracts of Carbon'94, Granada, Spain, p.270, Mochida, I., Kisamori, S., Kawabuchi, Y., Kuroda, K. and Kawano, S.

222. "Kinetic Study on the H_2SO_4 Recovery Desulfurisation over PAN-ACF and its Analysis", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.574, Mochida, I., Kuroda, K., Kisamori, S. and Kawano, S.

223. "Influences of Preparation Conditions of ACF on Catalytic Activity for SO_2 Removal", Extended

Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.534, Kim, J-Y, Hong, I. and Lee, J.G.

224. "Adsorption of NO_x and SO_2 with Activated Carbon Fibers", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.74, Park, B.B., Lee, Y.S., Shim, H.B., Ryu, S.K. and Rhee, B.S.

225. "Development of Combined NO and SO_2 removal Processes", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.358, Park, B.B., Lee, Y.S., Ryu, S.K .and Rhee. B.S.

226. "Activated Carbon Fibers from PAN. II: Catalytic Activity for SO_2 Oxidation", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.188 Martin-Gullon, I., Jagtoyen, M., Kimber, G. and Derbyshire, F.

227. "Activated Carbon Fibres from PAN–Steam and KOH Activation to Increase Catalytic Activity for SO_2 ", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.58, 1997, Martin-Gullon, I., Jagtoyen, M., Kimber, G., Derbyshire, F., Andrews, R. and Grulke, E.

228. "Effect of Heat Treatment Conditions on Activity of Activated Carbon Fibers for SO_2 Removal", Extended Abstracts for Eurocarbon '98, p.275, Strasbourg, France, 1998, Andrews, R., Raymundo-Pinero, E. and Derbyshire, F.

229. "SO_2 Adsorption on Activated Carbons and Activated Carbon Fibres: Influence of Surface Chemistry and Porosity", Extended Abstracts for Eurocarbon '98, p.341, Strasbourg, France, 1998, Raymundo-Pinero, E., Cazorla-Amoros, D., Salinas-Martinez de Lecea, C. and Linares-Solano, A.

230. "Adsorption of SO_2 onto Oxidized and Heat-Treated Activated Carbon Fibres (ACFs)", Carbon **35**, 411, 1997, Daley, M.A., Mangun, C.L., DeBarr, J.A., Riha, S., Lizzio, A.A., Donnals, G.L. and Economy, J.

231. "SO_2 Removal at Low Temperature by Modified Activated Carbon Fibres", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.70, Fuertes, A.B. and Muniz, J.

232. "Preparation of Active Carbon Fibre with Basic Properties", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.431, Yawabuchi, Y., Sotowa, C., Kuoda, K., Kawano, S., Whitehurst, D.D., and Mochida, I.

233. "Effect of Pore Size on Adsorption of Hydrocarbons in Phenolic-based Activated Carbon Fibres", Carbon **36**, 123, 1998, Mangun, C.L., Daley, M.A., Braatz, R.D. and Economy, J.

234. "The Structure of Mesophase Pitch-Based Chopped Fibre as Precursor of Activated Carbon Fibre", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.66, 1997, Watanabe, F., Korai, Y. and Mochida, I.

235. "Modification of Pores over Molecular Sieving Carbon and Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.520, Kawabuchi, Y., Kawano, S., and Mochida, I.

236. "Modification of Activated Carbon Fibre for Better Molecular Sieving", Abstracts for the Workshop on

Adsorbent Carbon, Lexington Kentucky, p.38, 1995, Kawabuchi, Y., Kawano, S. and Mochida, I.

237. "Surface Modification of Active Carbon Fibre by Selective CVD for Better Performance in Environmental Applications", Abstracts Carbon Material for the Environment , American Carbon Society Workshop, Charleston S.C. p.61, 1996, Mochida, I., Kawabuchi, Y., Sotowa, C., Yasutake, A. and Yoshikawa, M.

238. "The Modification of Pore Size in Activated Carbon Fibers by Chemical Vapour Deposition and its Effects on Molecular Sieve Selectivity", Carbon **36**, 377, 1998, Kawabuchi, Y., Oka, H., Kawano, S., Mochida, I. And Yoshizawa, N.

239. "Radon Adsorption in Activated Carbon Fibres by Open System", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.686, Nakayama, Y., Okada, Y., Shiraishi, K., Sasanaga, K., Nagao, H., Kawanuchi, Y. and Mochida, I.

240. "Activated Carbon Fibre: Fundamentals and Applications", Carbon **32**, 577, 1994, Suzuki, M.

241. "Comparison of the Adsorption of Humic Acids from Aqueous Solutions on Active Carbon and Activated Charcoal Cloths", Carbon **32,** 207, 1994, Starek, J., Zukal, A. and Rathousky, J.

242. "Adsorption of Organics Present in Air onto Activated Carbon Fibers", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.378, Subrenat, A., Subrenat, E. and Le Cloirec, P.

243. "Adsorption onto Activated Carbon Fibers: Application to Water and Air Treatments", Carbon **35**, 1307, 1997, Brasquet, C. and Le Cloirec "Adsorption Properties of Vapour-Protective Fabrics Containing Activated Carbon", Carbon **35**, 1295, 1997, Rivin, D. and Kendrick, C.E.

244. "Adsorption of Organics in Water onto Activated Carbon Fibers Correlation Between Adsorption Parameters and Molecular Structure", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.4, Brasquet, C., Subrenat, E. and Le Cloirec, P.

245. "Adsorption onto Fibrous Activated Carbon Applications to Water and Air Treatments", Abstracts Carbon Material for the Environment , American Carbon Society Workshop, Charleston, S.C. p.28, 1996, Le Cloirec, P., Brasquet, C. and Subrenat, E.

246. "Filter Configurations Used to Adsorb Organics onto Activated Carbon Cloth", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.124, Le Cloirec, P., Brasquet, C. and Subrenat, E.

247. "Different Kinds of Filters Used to Adsorb Organics onto Fibrous Activated Carbon", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.36, 1997, Le Cloirec, P., Le Bot, M. and Subrenat, E.

248. "Correlation Between Microscopic Observations and Macroscopic Adsorption Data of Activated Carbon Fibres", Extended Abstracts for Eurocarbon '98, p.101, Strasbourg, France, 1998, Brasquet, C., Rousseau, B., Estrade-Szwarckopf, H. and Le Cloirec, P.

249. "Volatile Organic Compound Removal by Activated Carbon Fabrics: New Adsorber Design",

Extended Abstracts for Eurocarbon '98, p.279, Strasbourg, France, 1998, Le Cloirec, P. Subrenat, A., Baleo, J.N., Subrenat, E. and Le Bot, M.

250. "Adsorption of Vanadium (III) on Activated Carbon Fibre from Waste Water", Extended Abstracts of Carbon'94, Granada, Spain, p.376, Jung, C.H., Oh, W.Z., Chung, H.H., Rhee, B.S. and Ryu, S.K.

251. "Removal of Chromium (VI) from Wastewater with a Packed Bed of Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.472, Ryu, S.K., Shim, J.W., Jung, H.H. Oh, W.Z. and Jung, C.H.

252. "Adsorption of Chromium Ions in Decontamination Liquid Waste on Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.474, Jung, C.H., Jung, H.H., Oh, W.Z., Ryu, S.K. and Rhee, B.S.

253. "Adsorption of Picolinic acid Chelated Metal Ions from Decontamination Liquid Waste on Activated Carbon Fibres", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.78, Jung, C.H., Lee, S.M., Oh, W.Z., Ryu, S.K. and Rhee, B.S.

254. "Adsorption of Metal Ions from Decontaminated Liquid Waste using Activated Carbons Fibers", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.8, Jung, C.H., Lee, S.M., Oh, W.Z., Rhee, B.S. and Ryu, S.K.

255. "Adsorption of Ni(II), Cu(II), Cr(VI) from Multicomponent Aqueous Solution by Pitch-Based ACF", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.242, Shim, J.W., Lee, S.M., Rhee, B.S. and Ryu, S.K.

256. "Elimination Behaviour of Metallic Ion from its Dilute Solution by Activated Carbon Fibre Under Applied Electrical Potentials", Extended Abstracts of Carbon'94, Granada, Spain, p.222, Tomizuka, I., Meguro, T., Kuwagaki, H., Chiba, A., Miyazaki, A. and Okamoto, M.

257. "Elimination of Copper Ion from its Dilute Solution by Activated Carbon Fibre Under Applied Electrical Potentials", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.476, Tomizuka, I., Miyazaki, A., Okamoto, M., Meguro, T. and Chiba, A.

258. "Sorption of Arsenic Compound from Water Solutions by Carbon Fibrous Materials", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.336, Glushachenko, O., Strelko, V., Shvetz, D. and Openko, N.

259. 'Electrosorption of Radioactive Ions from Electrochemical Decontamination Liquid Waste by ACF Felt Electrode", Extended Abstracts for Eurocarbon '98, p.335, Strasbourg, France, 1998, Jung, C.H., Moon, J.K., Park, S.Y., Lee, B.J., Oh, W.Z., Lee, S.M., Rhee, B.S. and Ryu, S.K.

260. "Studies on the Mechanism of the Reaction of Activated Carbon Fibers with Oxidants", Carbon **32**, 593, 1994, Fu, R., Zeng, H. and Lu, Y.

261. "The Reduction of Pt(IV) with Activated Carbon Fibres-An XPS Study", Carbon **33**, 657, 1995, Fu, R., Zeng, H., Lu, Y., Lai, S.Y., Chan, W.H. and Ng, C.F.

262. "The Adsorption and Reduction of Pt(IV) on Activated Carbon Fibre", Carbon **36**, 19, 1998, Fu, R., Lu, W., Zeng, H.

263. "Preparation of Platinum Loaded Carbon Fibre by Using a Polymer Blend", Carbon **35**, 1676, 1997, Ozaki, J., Ohizumi, W., Endo, N., Oya, A., Yoshida, S., Iizuki, T., Roman-Martinez, M.C. and Linares-Solano, A.

264. "Preparation of Platinum Loaded Porous Carbon Fibres by Using Polymer Blend", Extended Abstracts for Eurocarbon '98, p.439, Strasbourg, France, 1998, Ozaki, J., Oizumi, W., Oya, A., Illan, M.J and Linares-Solano, A.

265. "Preparation and Characterization of Silver-Containing Activated Carbon Fibres", Extended Abstracts for Eurocarbon '98, p.595, Strasbourg, France, 1998, Ryu, S.K., Kim, S.Y., Gallego, N.C. and Edie, D.D.

266. "Surface Characterization of Oxidized Activated Carbon Cloth", Carbon **35**, 1047, 1997, Polovina, M., Babic, B., Kaluderovic, B. and Dekanski, A.

267. "Surface Modification of Activated Carbon Cloth-Influence on Metal Ions Adsorption", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.532, Polovina, M. Babic, B., Kaludjerovic, B. and Stojanovic, B.

268. "Adsorption of Zinc and Cadmium Ions on Activated Carbon Cloth", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.2, Babic, B., Milonjic, S., Cupic, S., Polovina, M. and Kaluderovic, B.

269. "Surface and Adsorption Characterisations of Activated Carbon Fibers Treated with Ozone in Aqueous Solutions", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.578, Kim, C., Lee, J.K., Ryu, S.K. and Yoon, O.S.

270. "Functional Group of Carbon Fibers and Activated Carbon Fibers Treated With Ozone", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.264, Ko, K.R., Kim, C.G., and Ryu, S.K.

271. "Adsorption Mechanism of Supercritical Methane", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.480, Murata, K. and Kaneko, K.

272. "Methane Storage in Activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.516, Alcaniz-Monge, J., Cazorla-Amoros, D., Linares-Solano, A. and Oya, A.

273. "Methane Storage in Activated Carbon Fibres", Carbon **35**, 291, 1997, Alcaniz-Monge, J., de la Casa-Lillo, A., Cazorla-Amoros, D. and Linares-Solano, A.

274. "Molecular Sieve Properties of General Purpose Carbon Fibers", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.366, de la Casa-Lillo, M.A., Alcaniz-Monge, J., Cazorla-Amoros, D. and Linares-Solano, A.

275. "Characterization of Activated Carbon Fibre by CO_2 Adsorption at High Pressure and N_2 Adsorption Isotherms at 77K", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.94, Guillot, A. and Follin, S.

276. "New Production Technology of Pitch-Based Activated Carbon Fibre", Abstracts for the Workshop on

Adsorbent Carbon, Lexington Kentucky, p.8, 1995, Matsumura, Y.

277. "Carbon Fibers and Activated Carbon from Alternative Precursors", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.9, 1995, Fei, T.Q. and Derbyshire, F.J.

278. "Pore Size Distributions in Activated Carbon Fibers Using computer Simulations", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.30, 1995, McEnaney, B., Mays, T.J. and Edie, D.D.

279. "Visualised Pore Analysis of ACF by TEM", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.35, 1995, Endo, M., Oshida, K., Takeuchi, K. and Dresselhaus, M.S.

280. "X-ray Structure Studies on CCl_4 Confined in Micropores of Activated Carbon Fibres", Extended Abstracts for Eurocarbon '98, p.751, Strasbourg, France, 1998, Iiyama. T., Suzuki, T., Kaneko, K.

281. "Study on the Pitch-based Activated Carbon Fibres (PACFS)", Extended Abstracts for Eurocarbon '98, p.351, Strasbourg, France, 1998, Zhang, X.J. and Shen, Z.M.

282. "Adsorption Behaviour of Hydrocarbons on Slit-shaped Micropores", Langmuir **13,** 496, 1997, Matsumoto, A., Zhao, J.-X. and Tsutsumi, K.

283. "Pore-Size Control in Pitch Based ACF", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.38, 1997, Matsumura, Y., Kanata, T., Mondori, J., Yasuda, H. and Tamai, H.

284. "The Shape-Selectivity of Activated Carbon Fibres as a Palladium Catalyst Support", Carbon **34**, 429, 1996, Jin, H., Park, S.-E., Lee, J.M. and Ryu, S.K.

285. "The Characteristics of Cu-Cr-Ag Impregnated Carbonaceous Adsorbents", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.488, Jin, H., Jeong, S.Y., Suh, J.K., Kwon, O.Y., Park, S.-J., Lee, J.M. and Ryu, S.K.

286. "Adsorption of Ammonia on Activated Carbon Fibre KF1500", Extended Abstracts for Eurocarbon '98, p.277, Strasbourg, France, 1998, Guillot, A. and Poujardieu, L.

287. "The Effect of Carrier Pyrolysis and Activation Conditions on the Properties of Cr-Cu-Ag Sorbents", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.68, Zietek, S., Babel, K., Kieczewski, M. and Zakrzewski, R.

288. "Carbon Fibre Composite Molecular Sieves : Synthesis and Characterization", Extended Abstracts of Carbon'94, Granada, Spain, p.650, Burchell, T.D., Weaver, C.E., Derbyshire, F., Fei, Y.Q. and Jagtoyen, M.

289. "A Novel Carbon Fibre Based Porous Carbon Monolith", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.40, 1995, Burchell, T.D., Klett, J.W. and Weaver, C.E.

290. "Gas Sorption Technique for Characterising Carbon Fibre Composite Molecular Sieves", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.318, Fuller, Jr., E.L., Burchell, T.D. and Rogers, M.R.

291. "Carbon Fibre Composite Molecular Sieves : Activation, Pore Structure and Adsorptive Behaviour", Extended Abstracts of Carbon'94, Granada, Spain, p.654, Derbyshire, F., Fei, Y.Q., Jagtoyen, M., Kimber, G., Matheny, M., Burchell T.D. and Weaver, C.E.

292. "A Monolithic Carbon-Fibre Based Composite Adsorbent", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.749, Burchell, T.D.

293. "A Novel Process and Material for the Separation of Carbon Dioxide and Hydrogen Sulfide Gas Mixtures", Carbon 35, 1279, 1997, Burchell, T.D., Judkins, R.R., Rogers, M.R. and Williams, A.M.

294. 'Applications of Carbon Fibre Based Adsorbent Monoliths", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.44, 1997, Burchell, T.D.

295. "Dynamics of Butane Adsorption on Activated Carbon Fibre Composites", Extended Abstracts for Eurocarbon '98, p.565, Strasbourg, France, 1998, Jagtoyen, M., Johnson, R. and Derbyshire, F.

296. "Carbon Fibre Composite Molecular Sieve Electrically Regenerable Air Filter Media", United States Patent # 5,827,355, 1998, Wilson, K.A., Burchell, T.D. and Judkins, R.R.

297. "An Adsorbent Carbon Monolith for Natural Gas Storage", Extended Abstracts for Eurocarbon '98, p.671, Strasbourg, France, 1998, Burchell, T.D., Klett, J.W. and Rogers, M.R.

298. "Novel Activated Carbon Materials for Water Treatment", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.328, Jagtoyen, M., Lafferty, C., Kimber, G. and Derbyshire, F.

299."Dynamics of Butane Adsorption on Activated Carbon-Fibre Composites", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.144, Jagtoyen, M., Kimber, G., Fowler, C. and Derbyshire, F.J.

300. "Butane Adsorption on Activated Carbon Fibre Composites: Modelling and Simulation", Extended Abstracts for Eurocarbon '98, p.141, Strasbourg, France, 1998, Andrews, R., Jagtoyen, M. and Grulke, E.A.

301. "Carbon Fibre Composites for Gas Separation", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.23, 1995, Kimber, G.M.

302. "Strength of Activated Carbon Fibre Composites", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.31, 1995, Grulke, E.A. and Kimber, G.M.

303. "Carbon Composites from Pre-activated Carbon Fibres", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.518, Kimber, G.M., Derbyshire, F.J., Jagtoyen, M. and Fei, Y.Q.

304. "Carbonaceous Material with High Micropore and Low Macropore Volume and Process for Producing Same", United States patent # 5,071,820, Quinn, D.F. and Holland, J.A.F.

305. "Uniform Activation of Large Carbon Fibre Composites", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.244, Jagtoyen, M., Kimber, G. and

Derbyshire, F.J.

306. "A Carbon Fibre Based Monolithic Adsorbent for Gas Separation", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.158, Burchell, T.D., Judkins, R.R. and Rogers, M.R.

307. "Removal by the Physical Adsorption Method of Carbon Dioxide from Model Flue Gas Using Activated Carbon Fibre and Activated Carbon", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.72, Lee, G.D., Hong, I., Lee, J.G. and Kim, J.-Y.

308. "The Use of Carbon Fibre Composites as Substrate for a Zero Valent Metal Dechlorination System", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.14, 1997, Andrews, R., Grulke, E. and Lafferty, C.

309. "Dynamics of VOC Adsorption on Activated Carbon-Fibre Composites", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.60, 1997, Jagtoyen, M., Fowler, C., Andrews, R., Kimber, G. and Derbyshire, F.

310. "Composites Based on Porous Modified Fibres and Mineral Adsorbents, Their Properties and Application", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.536, Davydov, V.I., Stavitskaya, S.S., Gerasimenko, N.V., Petrenko, T.P. and Koryakov, S.G.

311. 'Fibrous Carbonaceous Materials -The Perspective Carriers for Immobilisation of Microorganisms", Extended Abstracts for Eurocarbon '98, p.377, Strasbourg, France, 1998, Kalenyuk, A., Mikhalovsky, S., Taranova, L. and Strelko, V.

312. "Adsorptive Properties of Activated Carbons Prepared from Kevlar", Proceedings of The Characterization of Porous Solids (COPS II), Alicante, Spain, 1990, p.319, Freeman, J.J., Gimblett, F.G.R., Hayes, R.A., Amin, Z.M. and Sing, K.S.W.

313. "Preparation of Adsorptive Properties of Activated Polyarylamide Chars", Extended Abstracts for the Twentieth Biennial Conference on Carbon, Santa Barbara, Ca., 1991, p.98, Freeman, J.J., Gimblett, F.G.R., Reynolds, A.J., Sing, K.S.W. and Tomlinson, J.B.

314. "Adsorption of Nitrogen and Water Vapour by Activated Kevlar Chars", Carbon **31**, 865, 1993, Freeman, J.J., Tomlinson, J.B., Sing, K.S.W. and Theocharis, C.R.

315. "Multi-Staged Carbonisation of Aramid Fibers", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.218, Yoon, S,-H., Kim, B.C., Korai, Y. and Mochida, I.

316. "Adsorption of Nitrogen and Water Vapour by Activated Nomex Chars", Carbon **33**, 795, 1995, Freeman, J.J., Tomlinson, J.B., Sing, K.S.W. and Theocharis, C.R.

317. "Microporous Texture of Activated Carbon Fibres Prepared from Aramid Fibre Pulp", Microporous Materials **11**, 303, 1997, Martinez-Alonso, A., Jamond, M., Montes-Moran, M.A. and Tascon, J.M.D.

318. "Textural Properties of Activated Carbon Fibres Prepared From Kevlar Flocks", Extended Abstracts of Carbon'94, Granada, Spain, p.662, Jamond, M., Martinez-Alonso, A. and Tascon, J.M.D.

319. "Porous Structure of Polyarylamide-based Activated Carbon Fibres,", Carbon **34**, 1201, 1996, Stoeckli, F., Centeno, T.A., Fuertes, A.B. and Muniz, J.

320. "Physicochemical Properties of Polymer-Based Porous Fibre Adsorbents", Extended Abstracts for Eurocarbon '98, p.357, Strasbourg, France, 1998, Bradley, R.H., Daley, R. and Cuesta, A.

321. "Preparation of Polyvinyl Alcohol Based Activated Carbon Fibre by the Aid of O_3," Proceedings of the 21st Biennial Conference on Carbon, Buffalo, N.Y., 1993, p.365, Lu, W.M., He. F. and Wang, M-.Z.

322. "An Initial Evaluation of Poly(vinylacetylene) as a Carbon Fibre Precursor", Carbon **33**, 757, 1995, and Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.38, Mavinkurve, A., Visser, S. and Pennings, A.J

323. "A Kinetic Modal for the Carbonisation of PBO Fibre", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.40, Newell, J.A., Edie, D.D. and Fuller, E.L.

324. "Factors Limiting the Tensile Strength of PBO-Based Carbon Fibres", Carbon **34**, 551, 1996, Newell, J.A. and Edie, D.D.

325. "Preparation of Carbon Fibres from Softwood Lignin by Atmospheric Acetic Acid Pulping", Carbon **36**, 1119, 1998. Kubo, S., Uraki, Y. and Sano, Y.

326. "Activated Carbon Fibres from Non-Conventional Pitch Precursors", Extended Abstracts for Eurocarbon '98, p.63, Strasbourg, France, 1998, Derbyshire, F., Jacques, D., Jagtoyen, M., Kimber, G, Rantell, T. and Vego, A.

327. "Porous Structure of PAN-Based Activated Carbon Fibres," Carbon **36**, 427, 1998, and Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.138, Ryu, Z., Zheng, J. and Wang, M.

328. "Pore Structure Analysis of PAN Based Activated Carbon Fibre", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.604, Li, Z., He, F. and Wang, M.

329. "The Preliminary Study of Chemically Modified ACF", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.142, Yang, Q., Zheng, J and Wang, M.

330. "Adsorption Kinetics of PAN Based Activated Carbon Fibre", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.383, Li, Z., He, F. and Wang, M.

331. "The Effect of Carbonisation Temperature of PAN Fibre on the Properties of Activated Carbon Fibre Composites", Extended Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.II.444, Lee, J.C., Lee, B.H., Kim, B.G., Park, M.J. and Lee, D.Y.

332. "The Effect of Carbonisation Temperature of PAN Fibre on the Properties of Activated Carbon Fibre Composites", Carbon **35**, 1479, 1997, Lee, J.C., Lee, B.H., Kim, M.J., Lee, D.Y., Kuk, I.H., Chung, H., Kang, H.S., Lee, H.S. and Ahn, D.H.

333. "Numerical Modelling of Adsorption Dynamics Through Activated-Carbon-Fibre Cloth", Extended

Abstracts of 23rd Biennial Conference on Carbon, Carbon '97, University Park, Penn. State, Pa, p.346, Lordgooei, M., Rood, M.J. and Rostam-Abadi, M.

334. "Adsorption Properties of Supported Superactivated Carbon", Extended Abstracts of the 22nd Biennial Conference on Carbon, Carbon'95, San Diego, Ca., p.380, Rivin, D. and Kendrick, C.E.

335."Adsorption Properties of Vapour-Protective Fabrics Containing Activated Carbon", Carbon **35**, 1295, 1997, Rivin, D. and Kendrick, C.E.

336.""Adsorption Properties of Vapour-Protective Fabrics Containing Activated Carbon", Abstracts Carbon Material for the Environment , American Carbon Society Workshop, Charleston S.C. p.28, 1996, Rivin, D.

337. "Relative Humidity Affects Protection Times of Charcoal Containing Textiles Against Methyl Salicylate (MS) Vapour", Extended Abstracts of the European Carbon Conference, Carbon'96, Newcastle upon Tyne, U.K., p.56, Papenfus, M., Eloff, C.C. and van Staden, J.F.

338. For Example: "Staging in Alkali Metal Intercalated Graphite as Characterized by X-Ray Diffraction and Raman Spectra", Carbon **19,**, 1981, Kwizera, P., Erbil, A. and Dresselhaus, M.S., "Properties of Activated Carbon Fibers", Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.9, 1991, Dresselhaus, M.S., Fung, A.W.P., Kuriyama, K., Rao, A.M., diVittorio, S.L. and Endo, M., "Microstructures of Activated Carbon Fibers as Studied by High Resolution Transmission Electron Microscopy" Abstracts for the Workshop on Adsorbent Carbon, Lexington Kentucky, p.10, 1991, Endo, M., Oshida, K., Shiraishi, M., diVittorio, S.L. and Dresselhaus, M.S., and "New Characterization Techniques for Activated Carbon Fibres", Carbon **30,** 1065, 1992, Dresselhaus, M.S., Fung, A.W.P., Rao, A.M., Vittorio, S.L., Kuriyama, K., Dresselhaus, G. and Endo, M.

339. For Example: "Stabilization and Carbonisation of PAN-Based Carbon Fibres as Related to Mechanical Properties", Carbon **29,** 621, 1991, Deurbergue, A. and Oberlin, A.

340. For Example: "Melt-Spun Non-circular Carbon Fibres", Carbon **24,** 477, 1986, Edie, D.D., Fox, N.K., Barnett, B.C. and Fain, C.C.

341. For Example: "Inhibition of Oxidation of Carbon-Carbon Composites by Bromination ", etc. Carbon **28,** pp.815, 825 & 831, 1990, Ho, C.T. and. Chung, D.D.L.

342. "Carbon Fibers", Marcel Dekker, Inc., New York, 1984, Donnet, J.-B. and Bansal, R.C.